Upper Rio Grande Basin Water Operations Review Draft Environmental Impact Statement

Lead Agencies: U.S. Army Corps of Engineers
Bureau of Reclamation
New Mexico Interstate Stream Commission

Abstract: The U.S. Army Corps of Engineers (Corps), Bureau of Reclamation (Reclamation), and the New Mexico Interstate Stream Commission (NMISC) prepared this Upper Rio Grande Basin Water Operations Review Draft Environmental Impact Statement (DEIS) to assess the potential consequences of proposed changes to water operations in the Rio Grande basin above Fort Quitman, Texas. The DEIS is programmatic and is not intended to authorize specific projects that may also be applied to the upper Rio Grande system. It is anticipated that a plan for water operations at existing Reclamation and Corps facilities will be developed. The DEIS presents alternatives to allow for the exercise of discretionary authority by Reclamation, the Corps, and the NMISC related to water operations and evaluates the environmental, economic, and social effects of these alternatives. Some of the issues considered include changing the channel capacity criteria at Albuquerque, storage or non-storage of Rio Grande water in authorized San Juan-Chama space in Abiquiu Reservoir, and operation of the Low Flow Conveyance Channel.

This DEIS has been prepared in compliance with the National Environmental Policy Act and Reclamation and Corps procedures and is intended to serve environmental review and consultation requirements pursuant to Executive Order 11990 (Wetlands Protection), Executive Order 12898 (Environmental Justice), the National Historic Preservation Act (Section 106), Endangered Species Act (Section 7[c]), and Indian Trust Asset policies.

Reviewers should provide comments during the 60-day review period of the DEIS to enable the lead agencies to analyze and respond to the comments, and to use information in the preparation of the final EIS. Comments on the DEIS should be specific and should address the adequacy of the information and analyses and the merits of the alternatives discussed (40 CFR 1503.3).

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Comments may also be submitted electronically at: http://www.spa.usace.army.mil/urgwops/.

Date Comments Must Be Received: March 21, 2006

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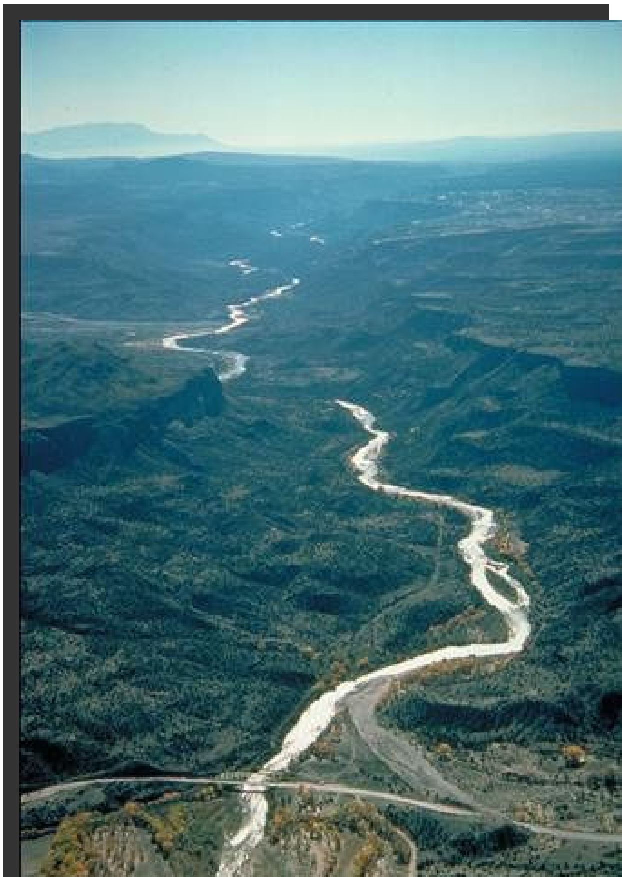
Upper Rio Grande Basin
Water Operations Review

Draft Environmental Impact Statement Summary



U.S. Army Corps of Engineers,
Albuquerque District

U.S. Department of the Interior,
Bureau of Reclamation

New Mexico
Interstate Stream Commission

January 2006

Acronyms and Abbreviations

Corps	U.S. Army Corps of Engineers
DEIS	Draft EIS
EIS	Environmental Impact Statement
ESA	Endangered Species Act
GIS	Geographic Information System
JLA	joint lead agencies
LFCC	Low Flow Conveyance Channel
MOA	Memorandum of Agreement
NEPA	National Environmental Policy Act
NMISC	New Mexico Interstate Stream Commission
NOI	Notice of Intent
SJC	San Juan-Chama
URGWOM	Upper Rio Grande Water Operations Model

Measurements

AF	acre-feet
cfs	cubic feet per second

SUMMARY

1.0 BACKGROUND

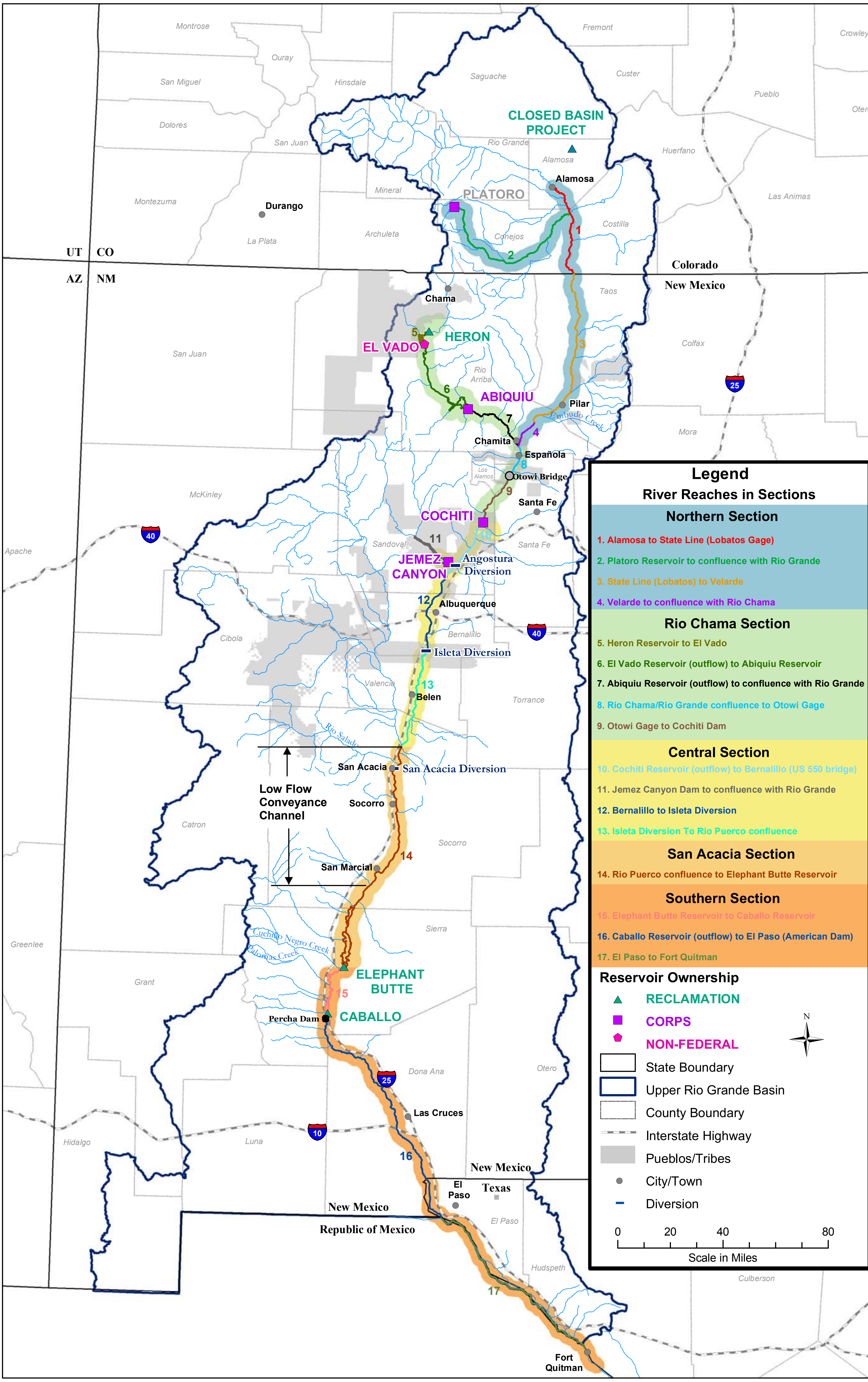
This draft programmatic environmental impact statement (EIS) considers the effects of adopting an integrated plan for water operations in the upper Rio Grande basin. The basin includes the Rio Grande from its headwaters in Colorado through New Mexico to just above Fort Quitman, Texas. The development of this EIS is the result of a Memorandum of Agreement (MOA), signed in 2000, defining the scope, purpose, and need for the project, the rules and responsibilities of each Joint Lead Agency (JLA) entering into the agreement, and the organizational structure for participation and oversight. The JLAs for this EIS are the U.S. Bureau of Reclamation (Reclamation), the U.S. Army Corps of Engineers (Corps), and the New Mexico Interstate Stream Commission (NMISC). The MOA stipulates that the JLAs undertake a review of water management practices in the upper Rio Grande, subsequently named the Upper Rio Grande Basin Water Operations Review (Review). This EIS is prepared in accordance with the National Environmental Policy Act of 1969 (NEPA), as amended (Public Law [P.L.] 91-910, 42 United States Code (U.S.C.) 4321-4347). NEPA requires every federal agency to give appropriate consideration to all reasonably foreseeable environmental impacts of proposed actions as part of agency planning and decision making. Therefore, any proposed activity that uses or crosses public land, or uses federal funds, must be reviewed by the federal agency for its potential environmental impacts or concerns. This EIS is being conducted in accordance with NEPA to identify and access potentially significant environmental, economic and social impacts and address other issues associated with changes in water operations of federally-operated facilities in the upper Rio Grande basin.

Water management in the Upper Rio Grande basin is a complex undertaking: several distinct federal and state agencies with differing missions and methods are responsible for legislating, managing, and distributing water. Several inter- and intra-state agreements mandate the delivery of certain volumes of water between federal, state, local and tribal entities. The portion of the river designated as the upper Rio Grande is subject to the Rio Grande Compact signed on March 18, 1938; ratified by the States of Colorado, New Mexico, and Texas in 1939; and signed by the President of the United States on May 31, 1939.

The climate of the Upper Rio Grande basin is variable: several years of above-average precipitation can be followed by several years of drought. Thus, the volume of available water to comply with agreements from year to year is equally variable. As a result, any water management plans for the area need to anticipate and proactively address wide-ranging hydrologic conditions.

Ten water operations facilities in this basin can be manipulated individually or in concert to address various situations. Five facilities are located on tributaries: Heron and El Vado Reservoirs operated by the U.S. Bureau of Reclamation (Reclamation), and Platoro, Abiquiu, and Jemez Canyon Reservoirs operated by the U.S. Army Corps of Engineers (Corps). The remaining facilities are on the mainstem of the Rio Grande, including Closed Basin Project operated by Reclamation in Colorado, Cochiti Reservoir operated by the Corps, and the Low Flow Conveyance Channel (LFCC) operated by Reclamation. In addition, two Reclamation facilities on the mainstem—Elephant Butte and Caballo Reservoirs—have operations limited to flood control under the scope of this EIS. **Map S-1** shows these facilities and **Figure S-1** highlights key features of the upper Rio Grande system. The New Mexico Interstate Stream Commission (NMISC) is authorized to protect, conserve and develop the waters of the state and monitors operations at reservoirs and water conveyance facilities for these purposes and to assure compliance with the Rio Grande Compact.

In addition to this summary document, the draft EIS contains two volumes. Volume I describes the proposed action, the alternatives considered, the analysis of potential effects of integrated water operation plan on the Rio Grande basin and environmental commitments associated with the action alternatives. Volume II contains attachments that are comprised of documents and other supporting material that provide detailed technical information concerning this proposed action.


Legend
River Reaches in Sections
Northern Section
1. Alamosa to State Line (Lobatos Gage)
2. Platoro Reservoir to confluence with Rio Grande
3. State Line (Lobatos) to Velarde
4. Velarde to confluence with Rio Chama
Rio Chama Section
5. Heron Reservoir to El Vado
6. El Vado Reservoir (outflow) to Abiquiu Reservoir
7. Abiquiu Reservoir (outflow) to confluence with Rio Grande
8. Rio Chama/Rio Grande confluence to Otowi Gage
9. Otowi Gage to Cochiti Dam
Central Section
10. Cochiti Reservoir (outflow) to Bernalillo (US 550 bridge)
11. Jemez Canyon Dam to confluence with Rio Grande
12. Bernalillo to Isleta Diversion
13. Isleta Diversion To Rio Puerco confluence
San Acacia Section
14. Rio Puerco confluence to Elephant Butte Reservoir
Southern Section
15. Elephant Butte Reservoir to Caballo Reservoir
16. Caballo Reservoir (outflow) to El Paso (American Dam)
17. El Paso to Fort Quitman
Reservoir Ownership
RECLAMATION
CORPS
NON-FEDERAL
State Boundary
Upper Rio Grande Basin
County Boundary
Interstate Highway
Pueblos/Tribes
City/Town
Diversion
0 20 40 80
Scale in Miles
N
CLOSED BASIN PROJECT
PLATORO
HERON
EL VADO
ABIQUIU
COCHITI
JEMEZ CANYON
ELEPHANT BUTTE
CABALLO
Alamosa
Durango
Chama
Pilar
Embudo Creek
Chamita
Española
Otowi Bridge
Santa Fe
Angostura Diversion
Albuquerque
Isleta Diversion
Belen
Rio Salado
San Acacia
San Acacia Diversion
Socorro
San Marcial
Low Flow Conveyance Channel
Cuchillo Negro Creek
Palomas Creek
Percha Dam
Las Cruces
El Paso
Fort Quitman
UT
CO
AZ
NM
Colorado
New Mexico
Texas
Republic of Mexico
Montrose
Ouray
San Miguel
Hinsdale
Saguache
Fremont
Custer
Crowley
Pueblo
Otero
Dolores
San Juan
Rio Grande
Alamosa
Huerfano
Mineral
Montezuma
La Plata
Archuleta
Conejos
Costilla
Las Animas
Taos
Colfax
Rio Arriba
Mora
McKinley
Los Alamos
Sandoval
Apache
Cibola
Bernalillo
Valencia
Torrance
Catron
Socorro
Sierra
Greenlee
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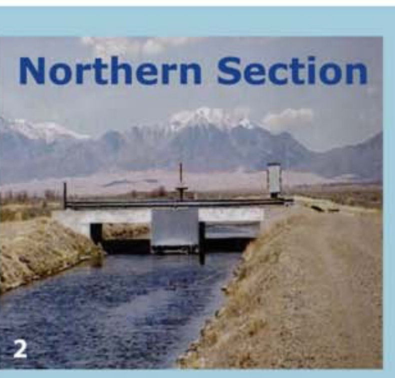
Dona Ana
Otero
Hidalgo
Luna
El Paso
Hudspeth
Culberson
40
25
10

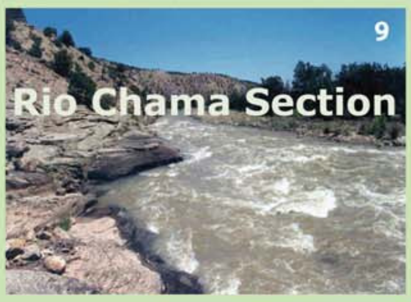


(1) From its source in the Rocky Mountains of south-central Colorado, the Rio Grande flows southeast to where the **Closed Basin Project (2)** outfall enters the river just north of **Alamosa (3)**.

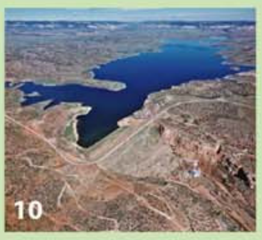
To the south, the river is joined by the Conejos River, on which **Platoro Reservoir (4)** is located near its headwaters.

The Rio Grande continues southward across the New Mexico state line, where it is supplemented upstream of **Pilar (5)** from three tributaries—Red River, Rio Hondo, Rio Pueblo de Taos—draining from the Sangre de Cristo Mountains to the east.

At the deepest portion of the **Rio Grande gorge (6)**, **Embudo Creek (7)** enters the river about 3 miles above the Embudo gage. The Rio Grande continues southward from Embudo to the confluence with the Rio Chama.



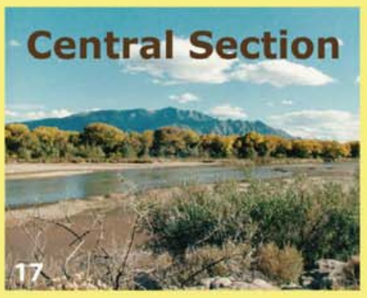
Heron Reservoir (8) is located upstream of Willow Creek's confluence with the Rio Chama. Imported water from the San Juan-Chama project is stored and released from Heron. To the south, the Rio Chama flows into El Vado Reservoir which stores spring runoff and irrigation water. The river then flows southeast where it is designated **Wild and Scenic (9)** between El Vado Dam and **Abiquiu Reservoir (10)**.



Abiquiu provides flood control, San Juan-Chama storage, and hydroelectric generation. There are numerous tributaries, small irrigation diversions, acreages, and communities in this **Chama section (11)**. major tributaries entering the river below Abiquiu include El Rito Creek and Rio Ojo Caliente.

The Rio Chama joins the Rio Grande 2.8 miles below **Chamita (12)**, in a delta area near the Pueblo of San Juan. In the 14 miles from the Rio Chama confluence to **Otowi Bridge (13)** and nearby gage, the Rio Grande flows through the Española Valley and is joined by three tributaries, Santa Cruz River, Santa Clara Creek and Rio Pojaque.

The Rio Grande then travels 27 miles downstream of Otowi Gage and forms a **delta area (14)** as it enters **Cochiti Reservoir (15)**. On Pueblo de Cochiti land, Cochiti Dam, the main flood control facility on the Rio Grande, prevents damages from floodwaters from the Rio Grande and the Santa Fe River.



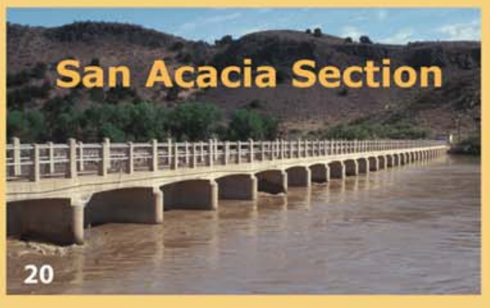
From above **Bernalillo (17)** through Albuquerque, the Rio Grande passes through river forest, urban and suburban areas, and irrigated fields.

On Isleta Pueblo land, the Rio Grande nourishes an adjacent wetland and provides irrigation water through the Isleta Diversion Dam, and continues southward past **Belen (18)**.

The MRGCD begins its irrigation diversions from the Rio Grande below Cochiti, where Galisteo Dam, a detention dam, limits discharge from Galisteo Creek, an east side tributary. Several other tributaries join the Rio Grande in the middle valley. One of the largest, the Jemez River, flows into the Rio Grande just below Angostura Diversion Dam.

Jemez Canyon Dam (16), on Santa Ana Pueblo land, was built to prevent damages from floodwater and is operated with Cochiti to prevent releases from exceeding channel capacity.

Below Bernardo, the Rio Puerco and the **Rio Salado (19)** enter the Rio Grande. These tributaries from the west contribute heavy sediment-laden flows to the Rio Grande.



About 55 miles downstream of the Isleta diversion, flow arrives at the **San Acacia Diversion Dam (20)**. Here, water is conveyed downstream through the Rio Grande (floodway) and the **Low Flow Conveyance Channel (21)**.

Historic population surveys of endangered Rio Grande silvery minnows indicated that the majority of its population are found in this reach from the diversion dam to Elephant Butte Reservoir.

Just upstream of the reservoir, the Rio Grande reaches a flow constriction point at the **San Marcial railroad bridge (22)**.

Elephant Butte Reservoir (23) is the principal storage facility for the Rio Grande Project, delivering water for downstream uses. Flowing from the reservoir, the river is joined by Cuchillo Negro and Palomas Creeks along the 18 miles to **Caballo Reservoir (24)**, a regulating reservoir that works in conjunction with Elephant Butte.

The USIBWC is responsible for flood control in the 106-mile reach of the **Rio Grande Canalization Project (25)** from Percha Dam to El Paso, and further south to **Ft. Quitman, Texas (26)**.

2.0 PURPOSE AND NEED FOR ACTION

Water management in the upper Rio Grande basin has evolved over decades, the result of separate and distinct authorizing legislation involving various federal and state agencies with differing missions and methods. Agency coordination became critical in the mid-1990s with the designation of two endangered species under the federal Endangered Species Act (ESA). To meet species and habitat needs, manage flows in the highly variable flow regime of the Rio Grande, and satisfy competing water demands exacerbated by a multiple-year drought, cooperative efforts were needed. The goal was to evaluate a full range of water operations in an integrated systems approach and to examine whether the full range of discretionary actions was being implemented for better ecosystem management.

Three JLA led the effort to develop an integrated plan for water operations at their existing facilities in the upper Rio Grande basin: Reclamation, the Corps, and NMISC. This project, the Water Operations Review (Review) and Environmental Impact Statement (EIS) for the upper Rio Grande basin, addresses the following proposed action: "The adoption of an integrated plan for water operations at existing Corps and Reclamation facilities in the Rio Grande basin above Fort Quitman, Texas." The JLA adopted the following purpose and need statements for this Review and EIS, based on their agency responsibilities and authorities.

Purpose—The Water Operations Review will be the basis of, and integral to, the preparation of the Water Operations EIS. The purposes of the Review and EIS are to:

1. Identify flexibilities in operation of federal reservoirs and facilities in the upper Rio Grande Basin that are within existing authorities of the Corps, Reclamation, and NMISC and that are in compliance with state and federal law.
2. Develop a better understanding of how these facilities could be operated more efficiently and effectively as an integrated system.
3. Formulate a plan for future water operations at these facilities that is within the existing authorities of the Corps, Reclamation, and NMISC, that complies with state, federal, and other applicable laws and regulations, and that assures continued safe dam operations.
4. Improve processes for making decisions about water operations through better interagency communications and coordination, and facilitation of public review and input.
5. Support compliance of the Corps, Reclamation, and NMISC with applicable laws and regulations, including, but not limited to, NEPA and the ESA.

Need—Under various existing legal authorities, and subject to the allocation of supplies and priority of water rights under state law, the Corps and Reclamation operate dams, reservoirs, and other facilities in the upper Rio Grande basin to:

1. Store and deliver water for agricultural, domestic, municipal, industrial, and environmental uses.
2. Assist the NMISC in meeting downstream water delivery obligations mandated by the Rio Grande Compact of 1938.
3. Provide flood protection and sediment control.
4. Comply with existing law, contract obligations, and international treaty.

2.1 Agency Coordination and Public Involvement

Five Cooperating Agencies, Bureau of Indian Affairs, U.S. Fish and Wildlife Service, New Mexico Department of Agriculture, New Mexico Environment Department, Pueblo of San Juan, signed formal agreements for participation in this Review and EIS. Each of these Cooperating Agencies provided team members and/or leadership on technical teams, contributed to review of findings during monthly Interdisciplinary NEPA Team meetings, and participated on the Steering Committee. The Interdisciplinary NEPA Team also included the participation of technical experts from other participating agencies. Project oversight and responsibility is the function of the Executive Committee, composed of the local officials of the lead agencies, which also provided project managers. The Steering Committee, composed of agency and tribal personnel, as well as interested stakeholders, facilitates coordination and information exchange with no decision-making role. Representatives from over 45 state and federal agencies and organizations, as well as many interested stakeholders, participated in technical resource teams, Interdisciplinary NEPA team meetings, and the Steering Committee. The organizational structure for this Review and EIS is shown in **Figure S-1.**

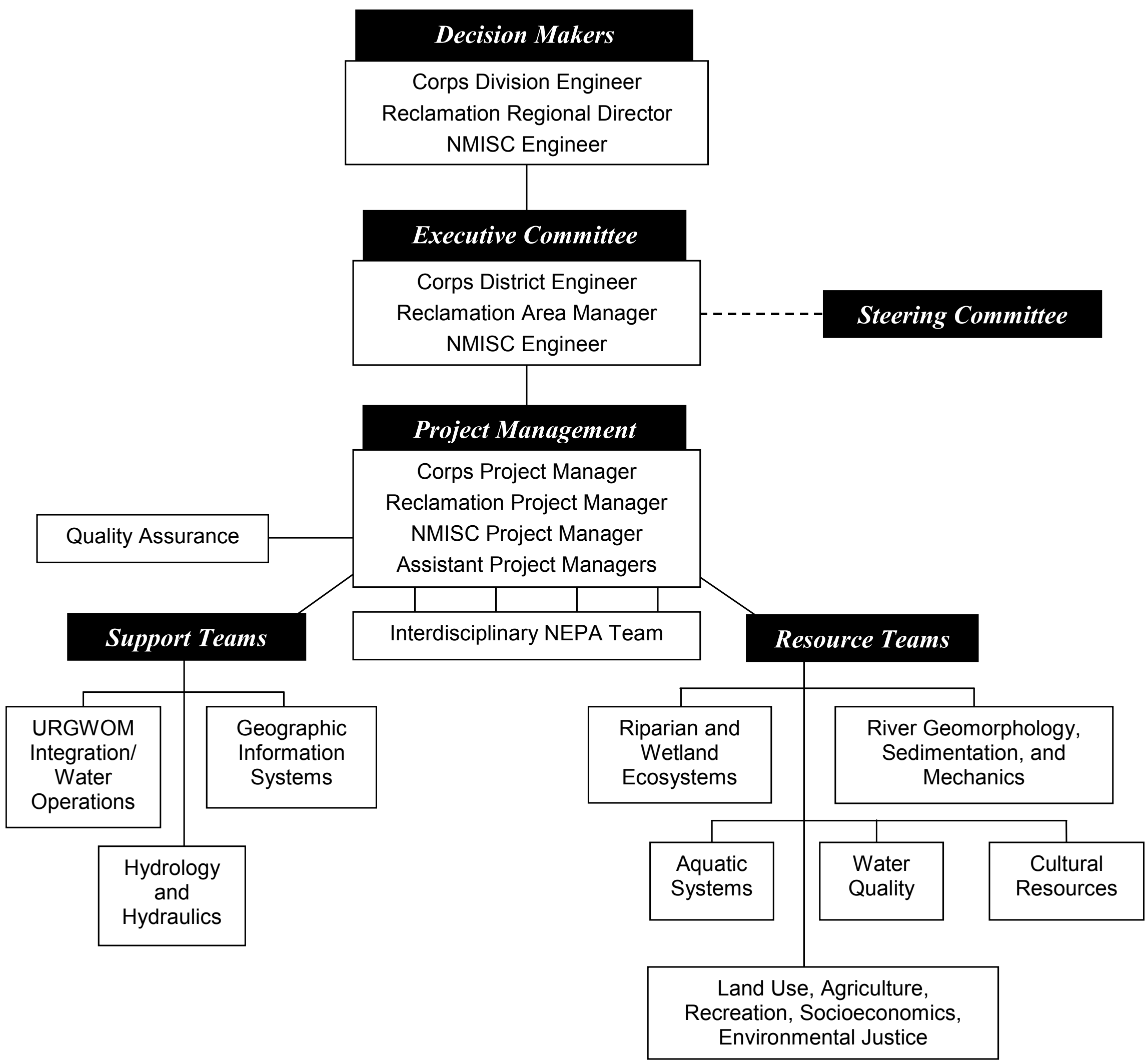


Figure S-1. Organizational Chart for the Water Operations Review and EIS

2.2 Public Involvement

In accordance with NEPA guidelines, a Notice of Intent (NOI) to prepare this EIS was published in the *Federal Register* on March 7, 2000. A news release announcing the NOI was sent to federal, tribal, state, and local officials; agency representatives; conservation organizations; news media; and others. The NOI and press releases to local newspapers also announced that a series of public scoping meetings that were held at nine locations in Colorado, New Mexico, and Texas to obtain input on issues that should be considered in the EIS. A total of 76 people, excluding members of the JLA, attended the public scoping meetings. Over 190 comments were documented from the written and oral comments submitted during and after the meetings. All comments were reviewed and categorized according to content.

During the scoping process in 2000, meeting attendees expressed an interest in learning about the alternatives before they were finalized and analyzed in the EIS. In response, the JLA invited interested stakeholders to participate in the Review and EIS by identifying possible alternatives to be considered that would reflect the full range of operating flexibilities for water management along the upper Rio Grande. In addition to a Steering Committee meeting, 10 public meetings were held in 2002 to discuss possible components of the alternatives and the strategy for developing them further in accordance with NEPA. The meetings on these draft alternatives were announced to more than 600 individuals and entities and publicized in the media, and attendance at the meetings ranged from 1 to 55 persons. Using the comments from the public, other agencies, and industry representatives, the interdisciplinary team developed a list of issues to address in the alternatives to be evaluated.

The issues identified through scoping and during alternatives development are briefly summarized below.

- **Low flows—**Improving water operations management flexibility during low flows is an important goal of this Review and EIS. While many of the operations and much of the infrastructure along the Rio Grande were developed to manage flood flows, in reality, the river is prone to drought and historically subject to frequent low flows that periodically leave parts of the channel dry and lead to increased sediment deposition.

- **Endangered species—**The river and adjacent riparian areas provide habitat to federally-listed endangered species, including the Rio Grande silvery minnow and the southwestern willow flycatcher. Provisions of the ESA require that operation of the river be consistent with the protection of listed species. The Review and EIS examines how changes to water operations may improve or maintain habitat for these species. As this is a 40-year planning study, the specific requirements of any current Biological Opinion were not considered in the analyses.

- **Water conveyance efficiency—**The Review and EIS examine improved efficiency in water conveyance through increased operational flexibility and coordination. Efficient conveyance of water to Elephant Butte Reservoir helps the United States meet its water delivery obligation to Mexico and helps the State of New Mexico meet its obligations under the Rio Grande Compact.

- **Sediment management and flood capacity of the channel—**The Review and EIS evaluates improved operations with the ability to mobilize sediment and keep the floodway open for flood flows. Management of the Rio Grande's heavy sediment load is fundamental to successful management of the river and its effect on adjacent lands. Adequate channel and floodway capacity are required to allow the higher flows of the Rio Grande to pass safely.

2.3 Key Tools

Due to the complexity and scope of the Review, a number of tools were developed and used in the evaluation of proposed plans for water operation. The Upper Rio Grande Water Operations Model (URGWOM) was the primary tool used for analysis and data projection. The URGWOM planning model is a software package that simulates hydrologic response to changes in reservoir operation, channel capacity, or water diversion based on defined physical characteristics of the system.

For modeling purposes, a 40-year hydrologic period was used. Daily water data for the years 1975-2000 were analyzed and randomly sampled to generate a hypothetical data set. These years were then projected from the year 2000 to the year 2040. In order to simulate a full range of possible hydrologic conditions that might be experienced in such a period, the sequence included a wet period, a drier than average period and a period of extreme drought. Most of the analyses of alternatives was based on data generated by this hypothetical 40-year projection. The model also considered typical irrigation demands and demands of the City of Albuquerque Drinking Water Project, assumed to be operating by year 4 of the 40-year planning period.

Other important tools in the review and EIS included FLO-2D, RMA-2/Aquatic Habitat Model, San Acacia Surface/Groundwater Model, and Geographic Information Systems (GIS) spatial analysis. The Criterium Decision Plus decision support model was used to aid in comparing and contrasting results of the alternatives. This suite of tools provides the best available information concerning the operation of the Rio Grande system.

3.0 ALTERNATIVES EVALUATED IN DETAIL

3.1 No Action Alternative

The No Action Alternative is the water operations alternative that depicts current storage and water delivery operations of federal facilities, including those changes in the system that are already published in the public record and will occur in the foreseeable future. For this project, it specifically means current operation of the ten water operations facilities in the basin, without integrating any of the flexibilities identified at Heron and Abiquiu Dams, Cochiti Lake, or the LFCC into a water operation plan (see Map S-1). The authorized function and current operation of each facility in the No Action Alternative that was considered and would be potentially affected by proposed changes is described briefly below:

- **Closed Basin Project (Reclamation)—**Located near Alamosa, Colorado, the Project uses wells to salvage groundwater from high water table conditions to assist Colorado in meeting its Rio Grande Compact delivery obligations. Salvaged groundwater varies in quality and is therefore blended to meet quality requirements of the Rio Grande Compact and the Clean Water Act. A network of observation wells monitors water levels in the underlying confined and unconfined aquifers to ensure that operations are within drawdown limits prescribed by the authorizing legislation. Well degradation and fouling is now limiting production. A well rehabilitation and replacement program is in progress.

- **Platoro Dam (Reclamation)—**Also in Colorado, Platoro Dam on the Conejos River is operated by the Conejos Water Conservancy District. A joint-use pool is used for both flood space and conservation; if flood space is needed, water in conservation storage is released to make room. A small permanent pool is maintained for recreation, fish, and wildlife. Platoro is managed to preserve fish and wildlife downstream. Flood control operation is the responsibility of the Corps and is the only function under review under the scope of this project.

- **Heron Dam (Reclamation)**—Heron Dam on Willow Creek in northern New Mexico stores no native Rio Grande water, therefore, this reservoir is not subject to Compact requirements. It was built in the late 1960s to store water from the upper Colorado River system and to import it to the Rio Grande through the San Juan-Chama (SJC) Project. Reclamation stores water in Heron Reservoir to meet the demands of its SJC Project water contractors who are required to take delivery of their annual allotment by December 31 of the irrigation year.
- **El Vado Dam (Reclamation)—**El Vado Dam is located on the Rio Chama. This reservoir was not part of the Review due to active litigation and changes to its operations were not considered.
- **Abiquiu Dam (Corps)—**Abiquiu Dam, also on the Rio Chama, is operated as a flood control facility. During flood control operations, water is released at a rate of up to 1,800 cubic feet per second (cfs) to evacuate the reservoir and maintain safe channel capacity downstream. The reservoir can also be used to store SJC Project water up to an elevation of 6,220 feet. The City of Albuquerque owns storage easements up to this elevation and has a current contract with the Corps to store SJC Project water in this incidental pool. The reservoir is also authorized to store native Rio Grande water in the SJC Project water space when this space is not needed. Such storage is subject to other requirements such as a state engineer permit, a Corps deviation from normal operations, and unanimous concurrence of the deviation by the Compact Commission.
- **Cochiti Dam (Corps)—**Cochiti Dam is a sediment and flood control structure located primarily on Pueblo of Cochiti lands. The Pueblo of Cochiti provided easements and rights-of-way for the facility and the Corps coordinates with the Pueblo on actions involving this reservoir. Cochiti Dam spans the main stem of the Rio Grande and the Santa Fe River tributary to the Rio Grande on Pueblo land, south of Santa Fe, New Mexico. The Corps has specific requirements for holding and releasing carry-over native Rio Grande floodwater in the facility. A permanent pool of SJC Project water is maintained in Cochiti Lake for recreation, fish, and wildlife. There is no authorization to store native Rio Grande water in Cochiti Lake.
- **Jemez Canyon Dam (Corps)—**A sediment and flood control structure on the Rio Jemez, Jemez Canyon Dam is operated as a dry reservoir. The dam and reservoir area are on Pueblo of Santa Ana lands and the Corps coordinates with the Pueblo on actions involving this reservoir. There are no water contracts in place or proposed for re-establishing a sediment pool.
- **Low Flow Conveyance Channel (Reclamation)—**The LFCC was constructed in the 1950s to aid delivery of Compact waters to Elephant Butte Reservoir. It also served to improve drainage and supplement water supply for irrigation. The riprap-lined channel parallels an approximately 60-mile reach in the San Acacia Section of the Rio Grande from San Acacia to San Marcial, New Mexico. The LFCC collects river seepage and irrigation surface and subsurface return flows, thus reducing evaporation. The usefulness of the LFCC is dependent upon the water level of Elephant Butte Reservoir. When outfall conditions allow, up to 2,000 cfs can be diverted into the LFCC at San Acacia. The LFCC also provides water to both Bosque del Apache National Wildlife Refuge and to irrigators in the Middle Rio Grande Conservancy District.

- **Elephant Butte Dam (Reclamation)—**Elephant Butte Reservoir is the primary water storage facility for Rio Grande Project water, delivered primarily to New Mexican, Texan, and Mexican irrigators living downstream of Caballo Reservoir. However, release of water for delivery to the downstream entities was not addressed in the Review and EIS. Generation of hydropower is a secondary purpose of the facility. Operation of the facilities for "prudent flood space" was included in the scope of this Review and EIS. A 50,000 acre-foot (AF) flood space is maintained from April 1 to September 30; 25,000 AF of flood space is reserved between October 1 and March 31. Flood release is required when the reservoir level is within the prudent flood space.

3.1.1 Action Alternatives

Based on public scoping, review of historic hydrologic extremes, and considering the breadth of possible events that could occur within a 40-year planning period, draft operational plans (designated by letters) were developed using combinations of facility-specific actions. These plans were further differentiated (designated by numbers) recognizing natural limitations and operational feasibilities under a range of climatic conditions. Some draft alternatives necessarily fell out in the initial screening process through application of the three preliminary screening criteria presented in the public scoping meetings: (1) the alternative is physically possible; (2) the alternative meets the Memorandum of Agreement purpose and need statement; and (3) the alternative is within the existing authorities of the agencies involved.

Action alternatives considered for detailed analysis were selected based on a review of preliminary URGWOM planning version results using the three threshold screening criteria, together with detailed water operations performance measures developed by the Water Operations Support Team, as well as consideration of significant issues identified by the public in the draft alternatives meetings. Threshold criteria included dam safety and flood control operations, Compact compliance, and meeting contractual water supply obligations. The alternatives which emerged from the screening process that are considered for implementation are listed below. **Table S-1** provides a brief synopsis of the key features of each alternative, listed by proposed changes from the No Action Alternative and organized by each facility identified as possessing operational flexibility.

Table S-1. Comparison of Alternatives Analyzed

Alternatives	Operation/Facility						
	Heron Waivers	Abiquiu Storage Capacity	Abiquiu Channel Capacity	Cochiti Channel Capacity	Diversions to LFCC	Elephant Butte and Caballo	Basin-wide
No Action[1]	April 30	0 AF[3]	1,800 cfs[4]	7,000 cfs	0–2,000 cfs	Informal coordination	Informal communication
B-3	Sept. 30	0–180,000 AF	1,500 cfs	8,500 cfs	No Change*	Protocol/ coordination	Improved communications
D-3	Aug. 31	0–180,000 AF	2,000 cfs	No Change	No Change	Protocol/ coordination	Improved communications
E-3[2]	Sept. 30	0–180,000 AF	No Change	10,000 cfs	No Change	Protocol/ coordination	Improved communications
I-1	No Change	0–20,000 AF	No Change	No Change	0–500 cfs	Protocol/ coordination	Improved communications

Alternatives	Operation/Facility						
	Heron Waivers	Abiquiu Storage Capacity	Abiquiu Channel Capacity	Cochiti Channel Capacity	Diversions to LFCC	Elephant Butte and Caballo	Basin-wide
I-2	No Change	0–75,000 AF	No Change	No Change	0–1,000 cfs	Protocol/ coordination	Improved communications
I-3	No Change	0–180,000 AF	No Change	No Change	No Change	Protocol/ coordination	Improved communications

*Note: *No Change* means no difference from No Action alternative. Modeled diversions to the LFCC begin only when there is at least 250 cfs in the river.

[1] Least flexible alternative. [2] Most flexible alternative. [3] AF = Acre feet. [4] cfs = Cubic feet per second.

The action alternatives are briefly described below.

- **Alternative B-3**—Alternative B-3 was chosen as an action alternative in order to evaluate the impacts of later water delivery (September 30 as opposed to April 30) from Heron Dam, to take advantage of the flexibility available to store native Rio Grande water in Abiquiu Reservoir, consider lower flows below Abiquiu Dam, and higher flows below Cochiti Dam.
- **Alternative D-3**—The primary differences between Alternative D-3 and the No Action Alternative are a later Heron waiver date (August 31), storage of native Rio Grande water in Abiquiu Reservoir, and a higher maximum flow below Abiquiu Dam.
- **Alternative E-3**—The primary differences between Alternative E-3 and the No Action Alternative are a later Heron waiver date (September 30), storage of native Rio Grande water in Abiquiu Reservoir, and a higher maximum flow in the channels below Abiquiu Dam and Cochiti Dam.
- **Alternative I-1**—The primary differences between Alternative I-1 and the No Action Alternative are storage of native Rio Grande water in Abiquiu Reservoir and a lower maximum diversion into the LFCC. These variations from No Action were included in an alternative to address concerns from the Interdisciplinary NEPA Team that a greater range of upstream storage and LFCC diversions should be analyzed in order to better understand the impacts to resources along the Rio Chama and the Rio Grande. It was also developed to increase the variation between alternatives in compliance with NEPA requirements.
- **Alternative I-2**—The primary differences between Alternative I-2 and the No Action Alternative are higher (greater than Alt. I-1) amounts of storage of native Rio Grande water in Abiquiu Reservoir and a lower maximum diversion into the LFCC. These variations were included in an alternative to address the same concerns from the Interdisciplinary NEPA Team as noted in Alternative I-1.
- **Alternative I-3**—The primary differences between Alternative I-3 and the No Action Alternative are high amounts of storage of native Rio Grande water in Abiquiu Reservoir and the maximum authorized diversion into the LFCC. These variations from No Action were included in an alternative to analyze the impacts to the system through exercising maximum flexibility in upstream storage and LFCC diversions in order to better understand the impacts on resources along the Rio Chama and the Rio Grande.

4.0 SUMMARY OF ENVIRONMENTAL CONSEQUENCES ANALYZED

The analyses of impacts on each resource was performed to estimate the amount of potentially significant change that a given resource might experience. Changes to a resource were considered from multiple perspectives including: 1) how much change is expected, 2) whether the change would be beneficial or detrimental, 3) our understanding of complex relationships in the system, and 4) the reliability of the results of the analysis. **Table S-2** summarizes the results of the analyses for each alternative by noting improved or decreased impacts to a range of criteria when compared to the impacts under the No Action Alternative. The criteria were selected by each technical team because they were determined to be relevant to the resource.

Technical teams submitted recommendations for mitigation measures that may be selected in the Record of Decision to minimize the significant impacts identified through the effects analyses. Mitigation measures were specifically proposed to minimize potential adverse impacts under the Preferred Alternative for the following resource areas: Recreation, Cultural Resources, Water Quality, Biological Resources (including aquatic habitat, riparian areas and wetlands, and threatened and endangered species habitat), and hydrologic impacts on the river system.

Table S-2. Comparison of Action Alternatives to No Action by Potential Impact

Criterion/Resource	Subcategory	ALTERNATIVES						
		No Action	B-3	D-3	E-3	I-1	I-2	I-3
Dam Safety & Flood Control		Adequate	Met	Met	Met	Met	Met	Met
Water Deliveries		Adequate	Met	Met	Met	Met	Met	Met
Compact & Treaty Compliance			Met	Met	Met			Met
Ecosystem	Riverine	—	—	—	—	—	—	—
	Reservoir	—	■	■	■	■■	■■	■■
	Riparian	—	■■	■	—	❑	—	■
	T&E Species - RGSM	—	—	—	—	❑	❑	—
	T&E Species - SWFL	—	■	■■	■■	❑	—	■■
	Other T&E Species	—	■	—	—	❑	—	■
Operating Flexibility	Reservoir	—	❑❑	❑❑	❑❑	❑	❑❑	❑❑
	River	—	—	—	—	—	—	—
Water Quality		—	❑	—	—	—	—	—
Sediment Management		—	■	■	■	■	■	■
Indian Trust Assets		—	❑	■	❑	—	—	—
Cultural Resources		—	❑❑	❑❑	❑❑	❑	❑❑	❑❑
Land Use	Agricultural	—	❑❑	❑	❑	—	—	❑
	Recreation	—	❑❑❑	❑	❑❑	—	❑	❑❑
	Other Land Uses	—	❑	❑	❑	—	❑	❑
	Hydropower	—	❑	❑❑❑	❑❑❑	❑❑	❑❑	❑❑❑
	Flood Control - Damages	—	❑❑	❑❑❑	❑❑	❑	❑❑	❑❑❑
Fairness & Equity	Environmental Justice	—	❑❑	■■■	■	—	❑	■■
			TR			EP		

Legend:				
	—	No Significant Impact	T&E =	Threatened & Endangered
	❑	Slight Improvement (10 percent or more)	RGSM =	Rio Grande Silvery Minnow
	❑❑	Moderate Improvement (25 percent or more)	SWFL =	Southwest Willow Flycatcher
	❑❑❑	Substantial Improvement (50 percent or more)	EP =	Environmentally-Preferred Alternative (based on Ecosystem Criteria)
	■	Slight Decrease (10 percent or more)	TR =	Top-Ranked Alternative
	■■	Moderate Decrease (25 percent or more)		
	■■■	Substantial Decrease (50 percent or more)		

4.1 Preferred Alternative

The Preferred Alternative was identified based on the resource impacts and performance relative to weighted decision criteria developed for the decision support system as shown on **Figure S-2**. By applying the rankings derived from the criteria in the decision-support software, Alternative B-3 was identified as the preferred alternative. This alternative is not the same as the environmentally preferable alternative, but was selected because it was the best at meeting the most criteria. No alternative was determined to be ideal for all resources.

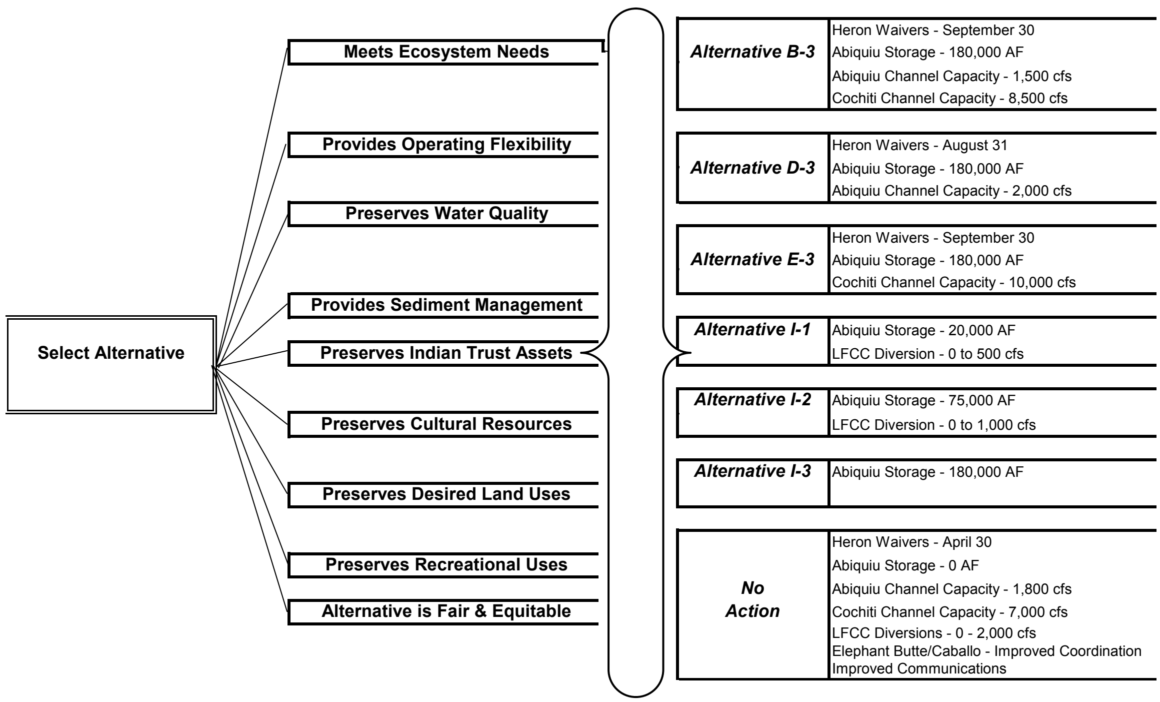


Figure S-2. Decision Hierarchy

Alternatives were evaluated by the technical teams using performance measures appropriate for each resource and scored for maximum benefit. Where quantitative analysis was possible, if an alternative provided the maximum benefit, it received a score of 100 percent. Alternatives with lesser results received a score reflecting the percentage of the maximum resource benefit attainable. Where quantitative information was not available, qualitative scoring was performed using simple scales ranging from 1 to 10 and descriptors such as good, fair, or poor. The final ranking of the alternatives is displayed graphically and in order from highest to lowest in **Figure S-3**.

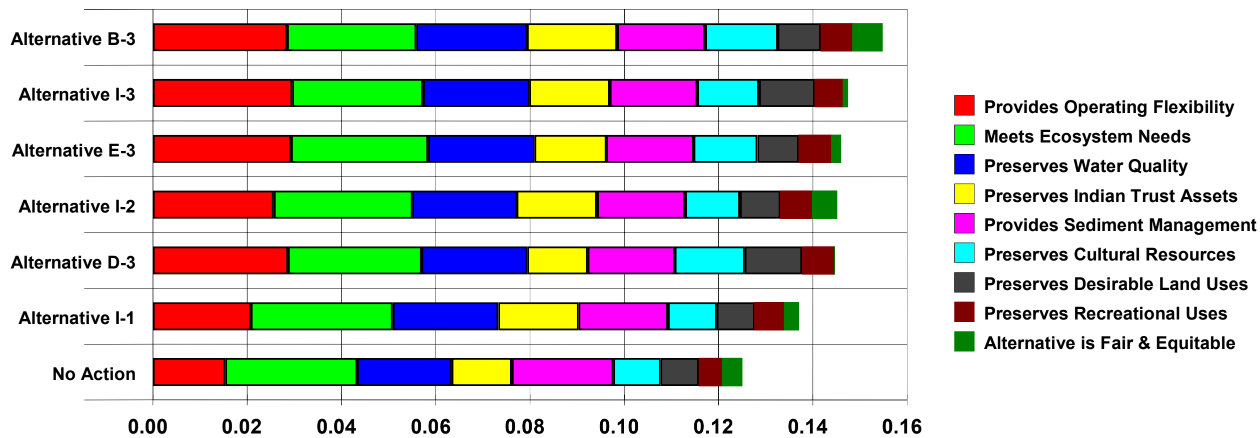


Figure S-3. Final Weighted Ranking of Alternatives

4.2 Cumulative Impacts

Council of Environmental Quality regulations implementing NEPA define cumulative impacts as "the impact on the environment which results from the incremental impact of action when added to other past, present, and reasonably foreseeable future actions regardless of which agency (Federal or non-Federal) or person undertakes such actions" (40 CFR section 1508.7). As this EIS considers a 40-year planning period, there are numerous past, present, and reasonably foreseeable actions in the planning area. This analysis focused on actions that may have a continuing, additive, or significant relationship to the impacts of the proposed alternative. This process was conducted by public scoping, consultation with cooperating agencies, tribal governments, and other stakeholders in the planning area, and through conversations among JLA representatives.

The identified actions for cumulative effects assessments were considered for actions implemented within the next 5 years, with operational impacts assessed for the 40-year planning period. The geographical scope of the analysis included the planning area extending from the Closed Basin Project in Colorado to Fort Quitman, Texas. Unless noted, cumulative impacts would be similar for all alternatives. The table is organized by resource, as presented in Chapters 3 and 4.

Table S-3 summarizes the cumulative impacts expected under the preferred alternative.

Table S-3. Summary of Cumulative Impacts

Project	Description	Time Period	Resource Impact
Bureau of Reclamation - Rio Grand and LFCC Modifications	This project proposes to realign the river channel and LFCC between San Acacia Diversion Dam and Elephant Butte Reservoir to improve water conveyance, enhance valley drainage, and improve sediment management.	Planning stages only; duration indefinite.	This EIS considers possible operating impacts for a reconfigured LFCC ranging from 500 to 2,000 cfs. However, changes due to physical realignment are not addressed. This project has the potential to affect flows in the San Acacia Section.

Project	Description	Time Period	Resource Impact
Bureau of Reclamation —Middle Rio Grande River Maintenance and Flood Protection	Reclamation maintains the river channel for the Middle Rio Grande Project from Velarde to Caballo Dam with the goals of effective water conveyance; water conservation; reducing aggradation; and protecting riverside structures and facilities.	Ongoing; duration indefinite	River maintenance activities complement the actions considered under water operations alternatives including bank stabilization, bioengineering, and habitat enhancements, river training works, sediment removal, vegetation control levee maintenance.
U.S. Army Corps of Engineers—Belen Levee Project	This project extends from Isleta Pueblo to Belen, NM along both banks of the Rio Grande. The existing spoil-bank levee would be rehabilitated to withstand higher and longer duration floods, accommodating the safe release of higher flows from upstream flood control reservoirs.	Planning stages; duration indefinite.	Completion of this project is critical to the implementation of any alternative that calls for a channel capacity greater than 7,000 cfs in the Central Section.
U.S. Army Corps of Engineers, Rio Grande Floodway Rehabilitation	This project affects the east bank of the Rio Grande from the san Acacia Diversion Dam downstream to the San Marcial Railroad bridge. This project will rehabilitate the existing spoil-bank levee and relocate and increase the channel capacity below the railroad bridge.	Planning stages; duration indefinite.	This EIS assumes that the San Marcial railroad bridges restriction on channel capacity is removed resulting in the ability to pass higher peak flows from upstream reservoirs. Completion of this project is critical to the implementation of any alternative that calls for a channel capacity greater than 7,000 cfs in the Central Section.
U.S. Army Corps of Engineers, Abiquiu Dam Oxygenator Project	This project considers modifications to the hydroelectric plant that would improve water quality below Abiquiu Dam in conjunction with power generation conducted by Los Alamos County.	Planning stages; duration indefinite.	Dissolved oxygen concentrations were a concern in the Southern Section - Elephant Butte and Caballo Reservoirs. Upstream improvements may also help downstream dissolved oxygen concentrations. This project will directly affect the Rio Chama Section, with lesser impacts downstream.
U.S. Army Corps of Engineers, Jemez Canyon Dam and Reservoir EA	This project considers long-term operation of Jemez Canyon Dam and Reservoir as a dry reservoir.	Court order; duration indefinite	This EIS treats Jemez Canyon Reservoir as a dry reservoir.
Middle Rio Grande Endangered Species Collaborative Program	This multi-agency and public collaborative program authorizes the planning, evaluation, and funding of projects to improve habitat, conduct research, and obtain water to benefit federally listed species.	Ongoing; duration indefinite	Adaptive management activities anticipated as a result of implementing the preferred alternative should be coordinated through the Collaborative Program to ensure that water operations changes are contributing to recovery efforts for the species.

4.3 Adaptive Management

In the upper Rio Grande basin, an adaptive management program would promote managing federal facilities within an overall scientific-economic policy framework where decisions are based on data resulting from scientific inquiry and measured impacts. This decision framework can be considered as "continuing NEPA in action." Under adaptive management, proposed actions are implemented, a period of monitoring and research occurs, and modified actions are implemented based on analysis of data collected, with cycles of further measurement and adjustment continuing to reach and sustain management objectives. Water managers and stakeholders must first agree on acceptable or desirable conditions (management objectives) specific to the Rio Grande and then commit to developing and practicing the art of adjusting operations to sustain those conditions.

Adaptive management activities in the Rio Grande system are underway. Multi-stakeholder collaborative efforts are ongoing in various portions of the basin, including the Middle Rio Grande ESA Collaborative Program and the Paso del Norte Watershed Council, and various regional water planning and watershed management groups.

Despite the actions of these agency and stakeholder groups, an overarching need exists for cooperative, adaptive management implementation across the entire planning area encompassing the federal facilities considered in this Review and EIS. A formal adaptive management program could be developed that extends from the Closed Basin Project and headwaters of the Rio Grande in Colorado to Fort Quitman, Texas with the charge of monitoring results of implementing the alternative adopted by the JLAs in individual agency Records of Decision.

The purpose of the adaptive management organization includes:

- Defining and recommending resource management objectives
- Conducting any additional research or studies to determine the impacts on various resources of the effects of operations conducted at Federal facilities along the Rio Grande
- Facilitating input and coordination of information among stakeholders
- Monitoring and reporting on regulatory compliance

4.3.1 Future Adaptive Management Activities

This EIS is a programmatic planning document and does not authorize specific projects. Rather, it provides a range of preferred water operations in the upper Rio Grande basin under the agencies' existing authorities. Any specific federal action proposed in the future would require its own NEPA process and environmental document. Detailed adaptive management plans would be developed as specific federal actions are proposed and implemented.

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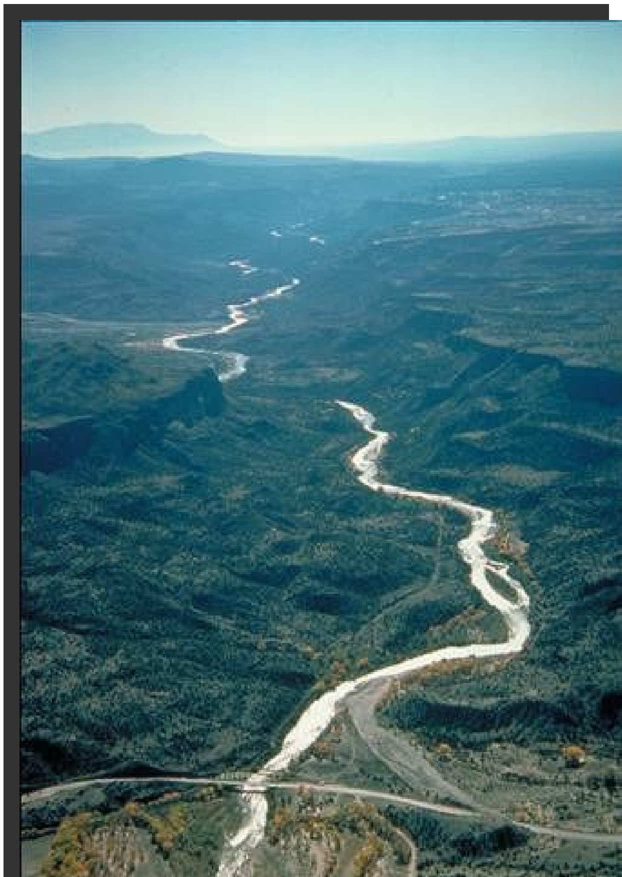
Upper Rio Grande Basin
Water Operations Review

Draft Environmental Impact Statement
Volume 1



U.S. Army Corps of Engineers,
Albuquerque District

U.S. Department of the Interior,
Bureau of Reclamation

New Mexico
Interstate Stream Commission

January 2006

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VOLUME 2: TECHNICAL TEAM REPORTS

Acronyms and Abbreviations

AAMDF	average annual mean maximum daily flow
BLM	Bureau of Land Management
CDP	Criterium Decision Plus ™
Census	U.S. Bureau of the Census
CFR	Code of Federal Regualations
CNG	compressed natural gas
Compact	Rio Grande Compact
Corps	U.S. Army Corps of Engineers
DEIS	Draft EIS
DO	Dissolved oxygen
DOE	Department of Energy
EA	Environmental Assessment
EIS	Environmental Impact Statement
ENSO	El Niño-southern oscillation
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FEIS	Final EIS
FEMA	Federal Emergency Management Agency
FR	Federal Register
FS	U.S. Forest Service
FWCA	Fish and Wildlife Coordination Act
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information System
HEC-RAS	Hydrologic Engineering Centers River Analysis System
ID	Interdisciplinary
ITA	Indian Trust Assets
IWR	Institute of Water Resources
JLA	joint lead agencies
LFCC	Low Flow Conveyance Channel
LPG	liquefied petroleum gas
MRGAA	Middle Rio Grande Administrative Area
MRGCD	Middle Rio Grande Conservancy District
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NMAC	New Mexico Administrative Code
NMAQB	New Mexico Air Quality Bureau
NMARMS	New Mexico Archaeological Records Management System
NMDGF	New Mexico Department of Game and Fish
NMDOL	New Mexico Department of Labor
NMED	New Mexico Environment Department
NMEMNRD	New Mexico Energy, Minerals and Natural Resources Department
NMISC	New Mexico Interstate Stream Commission
NMOSE	New Mexico Office of the State Engineer
NMSA	New Mexico Statutes Annotated
NMWQCC	New Mexico Water Quality Control Commission
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent

Acronyms and Abbreviations, cont'd.

NRHP	National Register of Historic Places
NWR	National Wildlife Refuge
OSE	Office of the State Engineer
P.L.	Public Law
Reclamation	U.S. Bureau of Reclamation
Review	Water Operations Review
RGCC	Rio Grande Compact Commission
RGSM	Rio Grande silvery minnow
ROD	Record of Decision
SJC	San Juan-Chama
Stat.	Statute
SWFL	Southwestern Willow Flycatcher
TCP	Traditional Cultural Properties
TDS	total dissolved solids
U.S.	United States
U.S.C.	United States Code
URGWOM	Upper Rio Grande Water Operations Model
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USIBWC	U.S. Section International Boundary and Water Commission
W&SR	Wild and Scenic River

Measurements

AF	acre-feet
AFY	acre-feet per year
cfs	cubic feet per second
db	decibels
ft	feet
ft^2	square feet
ft/mi	feet per mile
km	kilometer
kWh	kilowatt hour
mg/l	milligrams per liter
mm	millimeter
msl	mean sea level
MWh	megawatt hour
ppm	parts per million

Chapter I

Background

1.1 Introduction

The upper Rio Grande basin includes the Rio Grande from its headwaters in Colorado through New Mexico to just above Fort Quitman, Texas. This portion of the river is subject to the Rio Grande Compact signed on March 18, 1938; ratified by the States of Colorado, New Mexico, and Texas in 1939; and signed by the President of the United States on May 31, 1939. Ten water operations facilities in this basin can be manipulated individually or in concert to address various situations. Five facilities are located on tributaries: Heron and El Vado Reservoirs operated by the U.S. Bureau of Reclamation (Reclamation), and Platoro, Abiquiu, and Jemez Canyon Reservoirs operated by the U.S. Army Corps of Engineers (Corps). The remaining facilities are on the mainstem of the Rio Grande, including Closed Basin Project operated by Reclamation in Colorado, Cochiti Reservoir operated by the Corps, and the Low Flow Conveyance Channel (LFCC), operated by Reclamation. In addition, two Reclamation facilities on the mainstem—Elephant Butte and Caballo Reservoirs—are operations limited to flood control under the scope of this Review and EIS. **Map 1-1** shows these facilities and **Figure 1-1** highlights key features of the upper Rio Grande system. The New Mexico Interstate Stream Commission (NMISC) is responsible for Compact deliveries to Elephant Butte Reservoir, including, but not limited to, oversight of federal reservoir operations and accounting of native Rio Grande and San Juan-Chama (SJC) Project contract water.

1.2 Purpose and Need

Water management in the upper Rio Grande basin has evolved over decades, the result of separate and distinct authorizing legislation involving various federal and state agencies with differing missions and methods. Agency coordination became critical in the mid-1990s with the designation of two endangered species under the federal Endangered Species Act (ESA). To meet species and habitat needs, manage flows in the highly variable flow regime of the Rio Grande, and satisfy competing water demands exacerbated by a multiple-year drought, cooperative efforts were needed. The goal was to evaluate a full range of water operations in an integrated systems approach and to examine whether the full range of discretionary actions was being implemented for better ecosystem management.

Three joint lead agencies (JLA) have led the effort to develop an integrated plan for water operations at their existing facilities in the upper Rio Grande basin: Reclamation, the Corps, and NMISC. This project, the Water Operations Review (Review) and Environmental Impact Statement (EIS) for the upper Rio Grande basin, addresses the following proposed action: “The adoption of an integrated plan for water operations at existing Corps and Reclamation facilities in the Rio Grande basin above Fort Quitman, Texas.” The JLA adopted the following purpose and need statements for this Review and EIS.

Purpose—The Water Operations Review will be the basis of, and integral to, the preparation of the Water Operations EIS. The purposes of the Review and EIS are to:

1. Identify flexibilities in operation of federal reservoirs and facilities in the upper Rio Grande Basin that are within existing authorities of the Corps, Reclamation, and NMISC and that are in compliance with state and federal law.
2. Develop a better understanding of how these facilities could be operated more efficiently and effectively as an integrated system.
3. Formulate a plan for future water operations at these facilities that is within the existing authorities of the Corps, Reclamation, and NMISC, that complies with state, federal, and other applicable laws and regulations, and that assures continued safe dam operations.

4. Improve processes for making decisions about water operations through better interagency communications and coordination, and facilitation of public review and input.
5. Support compliance of the Corps, Reclamation, and NMISC with applicable laws and regulations, including, but not limited to, the National Environmental Policy Act (NEPA) and the ESA.

Need—Under various existing legal authorities, and subject to the allocation of supplies and priority of water rights under state law, the Corps and Reclamation operate dams, reservoirs, and other facilities in the upper Rio Grande basin to:

1. Store and deliver water for agricultural, domestic, municipal, industrial, and environmental uses.
2. Assist the NMISC in meeting downstream water delivery obligations mandated by the Rio Grande Compact of 1938.
3. Provide flood protection and sediment control.
4. Comply with existing law, contract obligations, and international treaty.

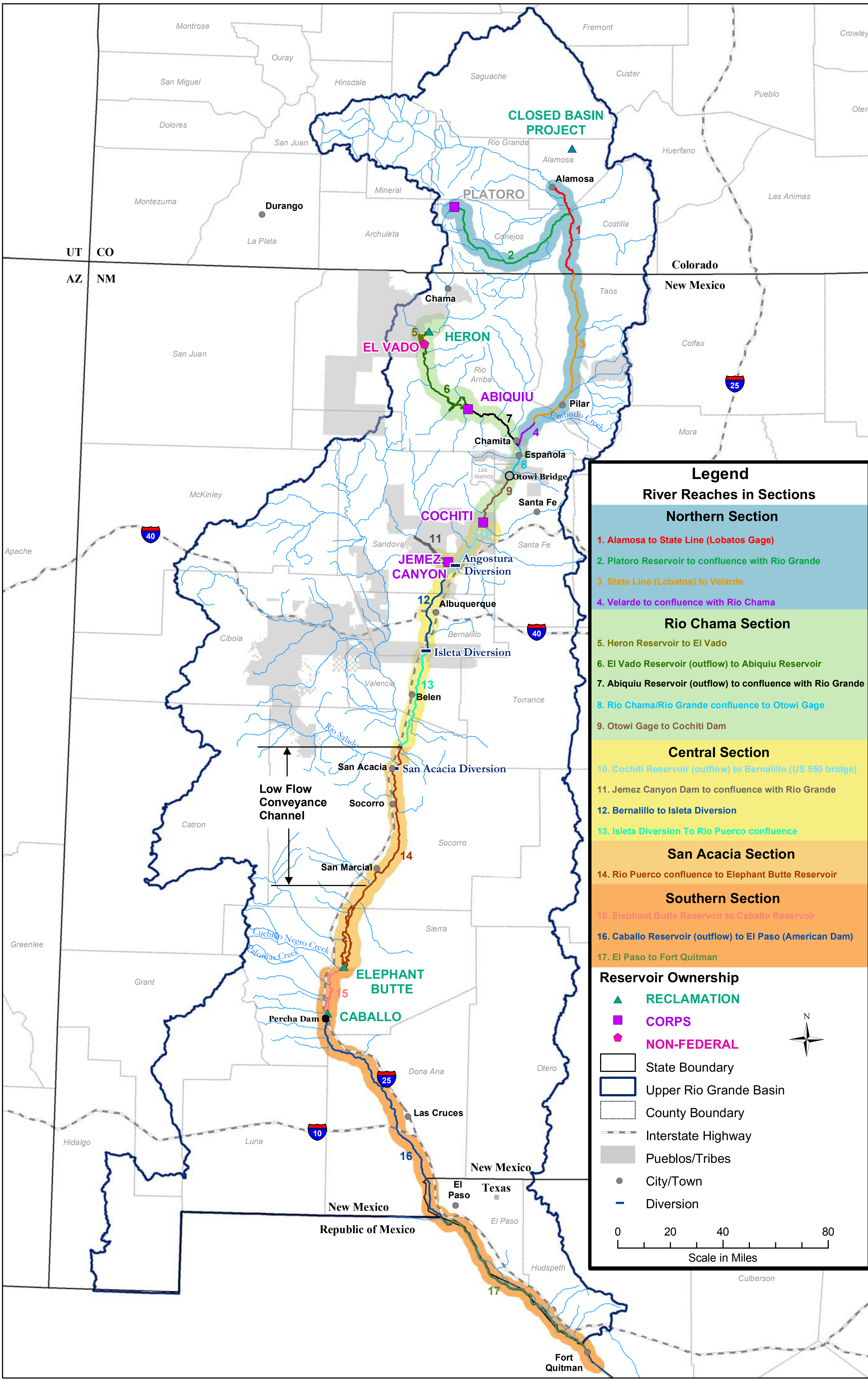
Because of the regulatory intricacies and multi-agency responsibilities, the Review and EIS is based on a Memorandum of Agreement signed in 2000 that defines the scope, purpose and need for the project, the roles and responsibilities of each of the JLA, and the organizational structure for participation and oversight. An organizational chart for this Review and EIS is shown in **Figure 1-2**. The Cooperating Agencies (described below under "Cooperating Agencies") signed formal agreements that commit resources to the effort, including participation in technical teams and an Interdisciplinary (ID) NEPA Team, along with technical experts from other participating agencies. Project oversight and responsibility is the function of the Executive Committee, composed of the local officials of the lead agencies. The Steering Committee facilitates coordination and information exchange with no decision-making role.

1.3 Cooperating Agencies

Five Cooperating Agencies (**Table 1-1**) signed formal agreements committing resources to the Review and EIS. Each of these Cooperating Agencies provided team members and/or leadership on technical teams, contributed to review of findings during monthly ID NEPA Team meetings, and participated on the Steering Committee.

Table 1-1. Cooperating Agencies for the Water Operations EIS

Agency Name	Agency Type	Primary Interest and Role
Bureau of Indian Affairs	Federal	Federal trust responsibility, Indian trust assets
U.S. Fish and Wildlife Service	Federal	Fish and Wildlife Coordination Act compliance
New Mexico Department of Agriculture	State	Irrigated agriculture economy, environmental justice
New Mexico Environment Department	State	Water quality protection and watershed management
Pueblo of San Juan	Tribal	Water quality, Indian trust assets, cultural resources



Map 1-1. Watershed and Key Water Operations Structures in the Upper Rio Grande Basin

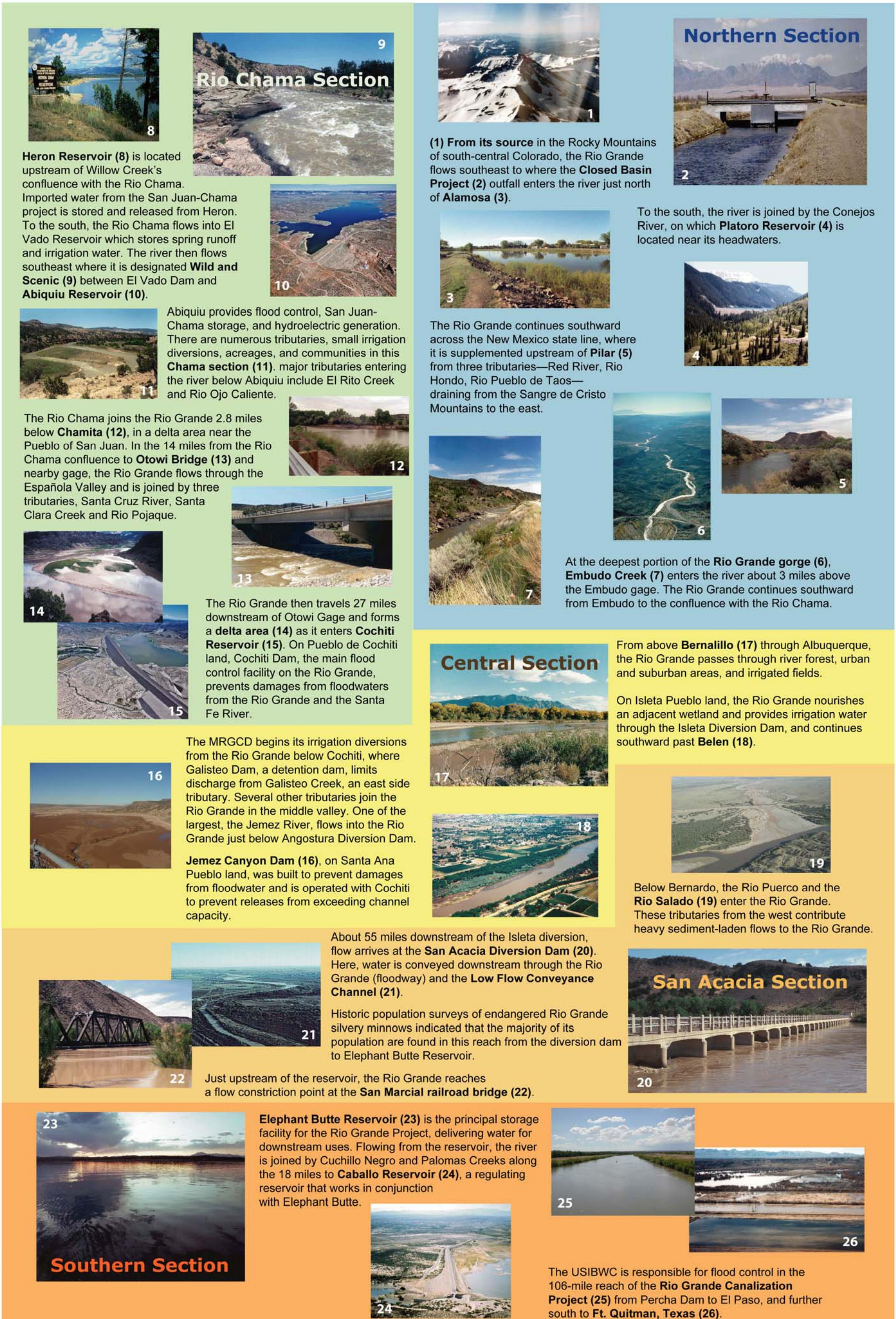


Figure 1-1. A Trip Down the Upper Rio Grande

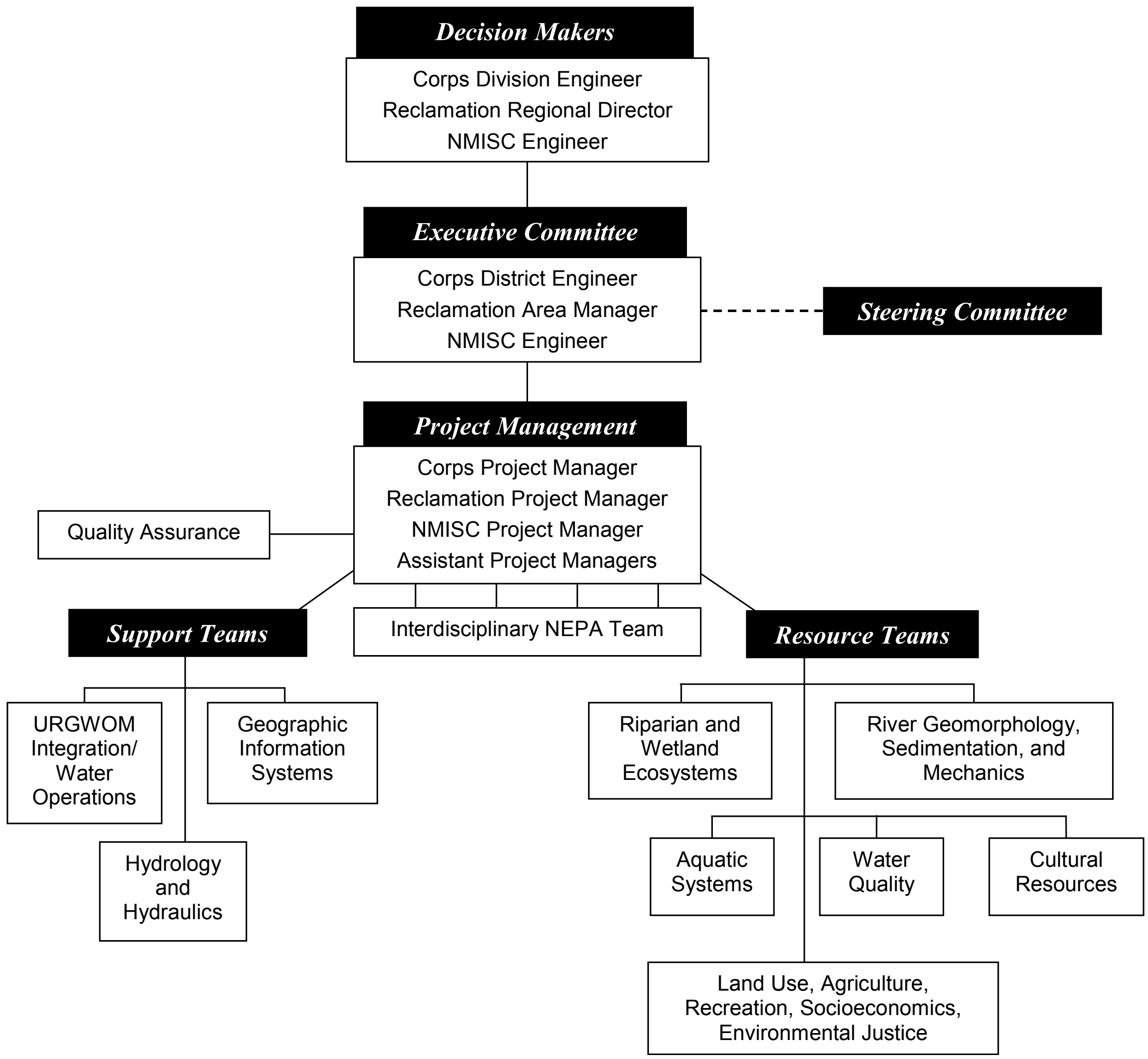


Figure 1-2. Organizational Chart for the Water Operations Review and EIS

Other entities contributed staff time in support of technical teams or the Steering Committee or assisted with public involvement activities (**Table 1-2**). Approximately 20 additional tribes, individuals and other groups that contributed to the NEPA process and Public Involvement were not assigned to a technical team.

Table 1-2. Other Entities that Supported Water Operations EIS

Name of Entity	Agency/Organization Type
International Boundary and Water Commission, U.S. Section	Federal
Bosque del Apache National Wildlife Refuge	Federal
U.S. Geological Survey	Federal
U.S. Bureau of Land Management	Federal
National Park Service	Federal
New Mexico Game & Fish Department	State
New Mexico Transportation Department	State

Name of Entity	Agency/Organization Type
New Mexico State Land Office	State
Middle Rio Grande Conservancy District	Water Provider
City of Albuquerque	Water Provider
Rio Grande Restoration	Conservation
Texas Commission on Environmental Quality	Rio Grande Compact Commission
Colorado State Engineer	Rio Grande Compact Commission
New Mexico State Engineer	Rio Grande Compact Commission
University of New Mexico	Research
New Mexico State University	Research
New Mexico Water Resources Research Institute	Research

1.4 Major Issues Affecting Water Operations

Major environmental and operational issues contributed to the need for the Review and EIS and required careful consideration during alternatives development and impacts analysis. These issues are listed below.

Low flows—Improving water operations management flexibility during low flows is an important goal of this Review and EIS. While many of the operations and much of the infrastructure along the Rio Grande were developed to manage flood flows, in reality, the river is prone to drought and historically subject to frequent low flows that periodically leave parts of the channel dry and increase sediment deposition. At the same time, the river is the major source of irrigation water supply in New Mexico, as well as El Paso County, Texas, U.S. and Ciudad Juarez, Chihuahua, Mexico.

Endangered species—The river and adjacent riparian habitats provide habitat to federally-listed endangered species, including the Rio Grande silvery minnow and the southwestern willow flycatcher. Provisions of the ESA require that operation of the river be consistent with the protection of listed species. The Review and EIS examines how changes to water operations may improve or maintain habitat for these species. As this is a 40-year planning study, the requirements of any current Biological Opinion were not considered in the analyses.

Water conveyance efficiency—The Review and EIS examine improved efficiency in water conveyance through increased operational flexibility and coordination. Efficient conveyance of water to Elephant Butte Reservoir helps the United States meet its water delivery obligation to Mexico and helps the State of New Mexico meet its obligations under the Rio Grande Compact.

Sediment management and flood capacity of the channel—The Review and EIS evaluates improved operations that have the ability to mobilize sediment and keep the floodway open for flood flows. Management of the Rio Grande's heavy sediment load is fundamental to successful management of the river and its effect on adjacent lands. Adequate channel and floodway capacity are required to allow the higher flows of the Rio Grande to pass safely.

Many of these issues are discussed in more detail in Chapter 3 under specific resource topics.

1.5 Special Considerations

1.5.1 Assumptions and Limitations of the Review and EIS

A preliminary review of upper Rio Grande basin water operations identified any constraints to federal flexibility that needed to be overcome. The following assumptions were made for this system-wide review of coordinated federal operations:

- The San Marcial railroad bridge was assumed relocated to increase channel capacity between San Marcial and Elephant Butte Reservoir. There is a Corps' project in progress to relocate the bridge (Corps 2003).
- Existing levees were assumed adequate to contain higher channel capacity releases. Current Corps and Reclamation projects address levee construction, replacement, or maintenance (Reclamation 2003b).
- Reservoir storage of native Rio Grande water was assumed available within City of Albuquerque flowage easements in Abiquiu Reservoir as the city implements its drinking water project using SJC project water currently stored there (Reclamation and City of Albuquerque 2002).
- A functional LFCC was assumed operational for the different diversion flows specified in the Action Alternatives, with an outfall to Elephant Butte Reservoir. The exact location and redesign of this facility is considered as part of another federal action (Reclamation 2000a).

Of the ten key facilities identified along the upper Rio Grande basin, the El Vado Dam and Reservoir and their operations were excluded by this Review and EIS due to ongoing litigation and a lack of flexibility in operations. Because this reservoir is not part of the Review and EIS, changes to its operations were not considered. Historic operation of the facility was modeled when evaluating alternatives.

The current March 2003 Biological Opinion (FWS 2003) presents the FWS opinion on the effects of actions on the endangered Rio Grande Silvery minnow, the endangered southwestern willow flycatcher, the threatened bald eagle, and the endangered interior least tern. The Biological Opinion presents effects associated with Reclamation's water and river maintenance operations, the Corps' flood control operation and related non-federal actions. This is a ten-year Biological Opinion and incorporates many aspects of water operations identified under the No Action Alternative, extending from the Colorado/New Mexico state line downstream to the headwaters of Elephant Butte Reservoir. The current Biological Opinion does not address active diversion to the LFCC or storage of native Rio Grande water in Abiquiu Reservoir. Since 2001, this is the third Biological Opinion in effect within the project area. Reinitiation of consultation is subject to many factors including exceeding incidental take; new actions or species listings; modified agency actions in a manner that causes negative effects on the listed species; changes in species population density; prolonged drought; and other factors. It is possible that other Biological Opinion requirements would be created during the 40-year planning period. Therefore, evaluation of ten-year Biological Opinion requirements was not explicitly performed in this forty-year evaluation of water operations alternatives.

1.5.2 Programmatic EISs, Tiering, and Site-Specific Impacts

This EIS is a comprehensive basin-wide planning document intended to support a broad range of operations conditions subject to highly variable hydrologic conditions. It is programmatic in nature, providing a preferred range of operations available at the federal reservoirs and facilities. Operating changes will change hydrology within the river system, including potentially beneficial and adverse impacts. This EIS is not intended to authorize specific projects that might also be applied to the upper Rio Grande system. However, it may provide the baseline data, models, and analysis that could be applied to future specific projects at the ten federal facilities considered or used in evaluating future coordinated management operations.

1.6 Related Projects and Activities

1.6.1 Authorized and Ongoing Actions

Related actions that are reasonable and foreseeable in the project area were considered in the evaluation of existing conditions and analysis of alternatives. Effects that were considered include those that may limit water operations flexibility, may affect alternatives, or provide additional baseline data.

U. S. Section International Boundary and Water Commission (USIBWC), River Management Alternatives for the Rio Grande Canalization Project, Final EIS (FEIS) (USIBWC 2004)—The USIBWC proposed actions are based on evaluating long-term river management alternatives for the Rio Grande Canalization Project. This project covers a 105.4-mile river corridor between Percha Dam, New Mexico and the American Dam in El Paso, Texas. The project component that applies to this Review and EIS is flood control at Elephant Butte and Caballo Dams. Measures considered to improve the riparian ecosystem while maintaining flood control and water delivery requirements include grazing lease modifications to improve erosion control, changes in floodway vegetation management, and aquatic habitat diversification.

U.S. Bureau of Reclamation, Relocation of Salvage Wells, Closed Basin Division, San Luis Basin Project, Colorado (Reclamation 2003b)—Reclamation proposed to redrill up to 170 new salvage wells over 10 years to assist Colorado in meeting its Compact delivery requirements. Each redrilled well will be located within 1 acre of an existing well. The Final Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) were issued on February 2003. The URGWOM planning version assumed no change to current production rates.

U.S. Bureau of Reclamation and City of Albuquerque, Drinking Water Project Final EIS (Reclamation and City of Albuquerque 2004)—Reclamation and the City of Albuquerque jointly prepared a DEIS in 2003 for the city's Drinking Water Project to efficiently use existing water resources to develop a safe and sustainable water supply by treating SJC Project water and native Rio Grande water. The Record of Decision (ROD) was signed June 2004. The city's projected diversions were included in URGWOM planning version data.

U.S. Bureau of Reclamation, Rio Grande and LFCC Modifications Draft EIS (Reclamation 2000a)—Reclamation's Draft EIS evaluates proposed modifications and realignment of the river channel and LFCC between San Acacia Diversion Dam and Elephant Butte Reservoir. The proposed actions are operating improvements and a realignment to convey water to Elephant Butte Reservoir in the LFCC channel, enhance valley drainage, and improve sediment management. The 2000 Draft EIS does not address LFCC operations. This EIS examines a range of LFCC operations in the alternatives.

U.S. Bureau of Reclamation and City of Albuquerque, Non-Potable Water Reclamation and Reuse, Northeast Heights and Southeast (Reclamation and City of Albuquerque 2001)—This EA and FONSI action includes the Non-Potable Surface Water Reclamation Project, the Southside Water Reclamation Plant Reuse Project, and an Arsenic Treatment demonstration component. The Nonpotable Water Reclamation project diverts SJC Project water near Alameda Boulevard to be combined with recycled industrial water to create a nonpotable water supply for turf irrigation. Construction is ongoing and partial deliveries are underway for turf irrigation.

U.S. Bureau of Reclamation, Middle Rio Grande River Maintenance and Flood Protection (Reclamation 2000b)—Reclamation maintains the river channel for the Middle Rio Grande Project from Velarde to Caballo Dam, involving the New Mexico portion of the project area. The goals of this project were: (1) providing effective transport of water and sediment to Elephant Butte Reservoir; (2) conserving surface water; (3) reducing the rate of aggradation; and (4) protecting riverside structures and facilities. Activities that complement operations covered by this Review and EIS include bank stabilization/

bioengineering / habitat enhancement techniques, river training works, sediment removal, vegetation control, levee maintenance, and access and construction requirements.

U.S. Army Corps of Engineers, Belen Levee Project (Corps 1999)—A draft supplemental DEIS/limited re-evaluation report was released for public review for this levee-rehabilitation project that extends from Isleta Pueblo to Belen, along both banks of the Rio Grande. The proposed action would rehabilitate the existing spoil-bank levee to withstand higher and longer-duration floods, and would allow for the safe release of higher flows from upstream flood-control reservoirs.

U.S. Army Corps of Engineers, Rio Grande Floodway, San Acacia to Bosque del Apache Unit, New Mexico (Corps 1997a)—This levee rehabilitation action on the east bank of the Rio Grande extends from the San Acacia Diversion Dam to downstream of the San Marcial railroad bridge. It proposes to rehabilitate the existing spoil-bank levee, and relocate and increase the capacity of the San Marcial railroad bridge. Alternatives evaluated in this Review and EIS assume that the San Marcial railroad bridge restriction on spring releases from upstream reservoirs will be removed. The project will result in better channel dynamics and a healthier riparian community given the ability to pass higher peak flows from upstream reservoirs.

U.S. Army Corps of Engineers, Abiquiu Dam Oxygenator Project EA (Corps 2001a)—This project covers construction improvements at the hydroelectric plant to improve water quality in the channel below the reservoir, in conjunction with power generation operations conducted by Los Alamos County using run of the river water flow quantities.

U.S. Army Corps of Engineers, Jemez Canyon Dam and Reservoir EA (Corps 2000)—This action was the release and drawdown of the reservoir pool prior to the expiration of the authorization. Court-ordered mediation resulted in the partial evacuation of the reservoir pool in the late summer and fall of 2000. Complete evacuation of storage occurred in the fall of 2001 with the project reverting to operation for the long term as a dry reservoir. This Review and EIS treats Jemez Canyon Reservoir as a dry reservoir.

Water Plans and Policy Initiatives—The Water Operations Review of the upper Rio Grande basin is also informed and guided by state and regional water plans and policy initiatives that have been developed for portions of the project area. These include the New Mexico State Water Plan, adopted in 2003 by the New Mexico Interstate Stream Commission, and the New Mexico Drought Plan, updated in 2003. The Middle Rio Grande Water Supply Study was a jointly funded study of the water budget for the portion of the river from Cochiti Dam to Elephant Butte Dam. The Office of the State Engineer and NMISC accepted the Jemez y Sangre Regional Water Plan in 2003. In 2004, the NMISC accepted the Middle Rio Grande and Socorro/Sierra County Regional Water Plans. The El Paso to Las Cruces Region Sustainable Water Project and the Far West Texas Regional Water Plan (Region E) both cover the portion of the Rio Grande from Elephant Butte Dam in New Mexico to Fort Quitman in Texas. These policies and plans will be taken into consideration as part of future adaptive management strategies (LBG-Guyton et al. 2001).

1.6.2 Foreseeable Future Projects

Other projects in early planning stages have not yet developed fully described actions. However, they may be considered in implementing future adaptive management strategies. These potential projects include the following:

Middle Rio Grande Endangered Species Collaborative Program Programmatic EIS. This project is jointly sponsored by Reclamation, Corps, NMISC, and several other signatories to a Memorandum of Understanding. It is a multiple-agency and public collaborative program that authorizes the planning, evaluation, and funding of projects to improve habitat, conduct research and obtain water in the Middle

Rio Grande area to benefit Rio Grande endangered species and comply with Rio Grande Compact deliveries and state and federal law, while allowing for continued and future human water uses.

Buckman Water Diversion Project. This project is sponsored by the United States Department of Agriculture Forest Service, the City of Santa Fe, the County of Santa Fe, and Las Campañas, a private entity. It is a project to divert, collect, and treat SJC Project and native Rio Grande water to meet peak municipal needs in the Santa Fe area.

1.7 Compliance with Applicable Laws and Regulations

This Review and EIS is subject to and consistent with applicable federal, state, and tribal laws, regulations, policies, and interstate compacts. A list of applicable laws, regulations, and treaties is provided in Appendix G, Comprehensive List of Laws and Regulations.

1.7.1 Federal Environmental Laws

1.7.1.1 National Environmental Policy Act

This document is prepared in accordance with NEPA 1969, as amended (Public Law [P.L.] 91-910, 42 United States Code (U.S.C.) 4321-4347). Written responses to comments will be published in the Final EIS (FEIS). A Notice of Availability will be published in the Federal Register announcing the availability of the FEIS. Release of a ROD usually concludes the NEPA process.

1.7.1.2 Endangered Species Act

The Endangered Species Act of 1973, as amended (P.L. 93-205, 87 Stat. 884, 7 U.S.C. § 136; 16 U.S.C. 460 et seq. [1973]) ("ESA") provides a comprehensive program for the conservation of threatened and endangered plant and animal species and the habitats in which they are found. ESA's blueprint for protection and recovery requires identification and listing of endangered species; designations of "critical habitat"—habitat that is essential to the continued existence of the species; preparation of recovery plans for the species; prohibitions against federal activities that are likely to jeopardize the continued existence of the species or that will adversely modify their critical habitat; and prohibitions against "taking" an endangered species that apply to government and private activities or actions.

1.7.1.3 Clean Water Act

The Clean Water Act (Federal Water Pollution Control Act, 33 U.S.C. §1251 et seq.) provides for surface water quality protection in the United States. It employs a variety of regulatory and nonregulatory tools to reduce pollutant discharges into waterways and manage polluted runoff to restore and maintain the chemical, physical, and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." Regulatory oversight is provided by the U.S. Environmental Protection Agency, which, in many cases, has delegated primacy for enforcement to states or tribal governments.

1.7.2 Laws Specific to the Rio Grande

1.7.2.1 Rio Grande Compact

The Rio Grande Compact (Compact) is an interstate agreement between New Mexico, Colorado and Texas to equitably apportion the water of the Rio Grande between the three states and the Republic of Mexico. The Compact was approved by Congress on May 31, 1939 and is administered pursuant to NMSA 1978, §72-15-23 (1945). A Rio Grande Compact Commission was established consisting of one representative from each state and a United States-designated representative.

1.7.2.2 Other Laws Affecting the Rio Grande

Specific laws and regulations that govern the operations and facilities that this project considers are listed here according to each responsible agency. In addition, a variety of general laws governs all federal actions and are therefore, utilized in the technical sections.

U.S. Army Corps of Engineers

1. Flood Control Act of 1940 (P.L. 78-534, 58 Stat. 890, 33 U.S.C. 709), Section 7 states that Flood Control Regulation for Platoro Reservoir, Conejos River, Colorado is the responsibility of the Corps.
2. Flood Control Act of 1944 (58 Stat. 890 U.S.C. 709), Section 7 states that Flood Control Regulation for Platoro Reservoir, Conejos River, Colorado is the responsibility of the Corps.
3. Flood Control Act of 1948 (P.L. 80-858) and the Flood Control Act of 1950 (P.L. 81-516) authorized construction of Abiquiu Dam.
4. P.L. 86-645 (1960) authorizes construction of Cochiti and Galisteo Dams and includes operation criteria for Jemez Canyon, Abiquiu, Cochiti, and Galisteo Dams.
5. P.L. 88-293 (1964) authorizes a permanent pool in Cochiti Lake for recreation and fish and wildlife. The pool was established and maintained with SJC Project water.
6. P.L. 97-140 (1981) authorizes up to 200,000 acre-feet (AF) of contract storage of SJC project water in Abiquiu Reservoir with certain conditions.
7. P.L. 100-522 (1988) authorizes storage of Rio Grande system water (up to 200,000 AF) in Abiquiu reservoir in the SJC storage space, if the SJC entities no longer require such storage. The storage of the Rio Grande system water is subject to provisions of the Rio Grande Compact.
8. Corps of Engineers regulations for implementing NEPA (33 CFR 230)

Bureau of Reclamation

1. The Reclamation Act of 1902.
2. The Flood Control Acts of 1948 (P.L. 80-858) and 1950 authorize construction, operation, and maintenance of channel rectification works of the Middle Rio Grande Project, which includes the LFCC.
3. P.L. 87-483 (1962) authorizes the SJC Project.
4. P.L. 92-514 (1972) authorizes the Closed Basin Project in Colorado to salvage groundwater that would otherwise be lost to evapotranspiration. The project helps the State of Colorado meet its required compact deliveries to New Mexico and facilitates delivery requirements to the Republic of Mexico.
5. P.L. 93-493 (1974) authorizes a recreation pool of 50,000 AF at Elephant Butte. The State of New Mexico has contracted with the City of Albuquerque for SJC Project water to maintain the recreation pool since 1985.
6. Reclamation's NEPA regulations (45 FR 47944 [7/17/80] as amended by 48 FR 17151 [4/21/83]).
7. Reclamation Reform Act of 1982 (P.L. 97-293, Title II, 96 Stat. 1263).

State of New Mexico

The Interstate Stream Commission, as JLA, is responsible for ensuring compliance with New Mexico State law. Specific laws and regulations that are applicable to this EIS include, but are not limited to the following:

1. Rio Grande Compact of 1939. NMSA 1978, § 72-15-23 (1945).
2. New Mexico Constitution. N.M. CONST. art. XVI.

3. New Mexico Water Code. Chapter 72 New Mexico Statutes Annotated 1978 (2004) (appropriation and use of surface water: NMSA 1978, §§ 72-5-1 et seq.; appropriation and use of ground water: NMSA 1978, §§ 72-12-1 et seq.).
4. Interstate Stream Commission Act. NMSA 1978, §§ 72-14-1 et seq.(1935).
5. Joint Powers Agreements Act, NMSA 1978, §§ 11-1-1 to –7 (1961).
6. New Mexico Office of the State Engineer Rules and Regulations Governing Drilling of Wells and Appropriation and Use of Ground Water in New Mexico (1995).
7. New Mexico Office of the State Engineer Surface Water Administration Rules and Regulations (2005).
8. New Mexico Office of the State Engineer Middle Rio Grande Administrative Area (MRGAA) for Review of Water Rights Applications (2000).
9. New Mexico Office of the State Engineer Mesilla Valley Administrative Area Guidelines for Review of Water Right Applications (1999).
10. Active Water Resource Management, Part 19.25.13 New Mexico Administrative Code (NMAC) 2005.
11. Ground and Surface Water Protection, Part 20.6.2 NMAC 2005.
12. Standards for Interstate and Intrastate Surface Waters, Part 20.6.4 NMAC 2005.

1.7.3 Federal Trust Responsibilities to Pueblos and Tribes

Federal laws and treaties established reservations and protect the rights of Native Americans to express, believe, and exercise traditional religious practices. Federal agencies are responsible for consulting with Indian tribal governments and traditional religious leaders to determine appropriate actions necessary for protecting and preserving Native American religious cultural rights and practices. Some federal laws and guidance are listed in Appendix G.

1.8 Organization of Document

- Chapter I – Discusses the purpose of and need for the action and also provides some of the issues and considerations that shaped the planning process.
- Chapter II – Describes the No Action Alternative and the Action Alternatives and the process and constraints under which they were derived, and identifies those selected for or eliminated from further study.
- Chapter III – Characterizes the existing environment, particularly the resources most affected by the alternatives carried forward for further analysis.
- Chapter IV – Discusses the environmental impacts of the viable Action Alternatives and the No Action Alternative, and concludes with a description of the Preferred Alternative.
- Chapter V – Discusses agency coordination, tribal consultation, scoping and public involvement conducted to obtain stakeholder participation in this Review and EIS.
- Chapter VI – Identifies factors identified as possible actions that could be implemented but are currently outside the authority of the JLA and beyond the scope of this Review and EIS.
- Chapter VII – Lists the preparers and contributors to this Review and EIS.

Following the chapters are two volumes of appendices. The first volume includes a bibliography, quality assurance plan, glossary, agency agreements, public involvement plan and reports, administrative record, ROD, and a list of applicable laws and regulations. The second volume compiles the multidisciplinary technical reports of analyses performed for this Review and EIS.

Chapter II

Development of Action Alternatives

2.1 Planning for Positive Benefits

To address highly variable water supply and competing demands along the Rio Grande, the water managers realized that they needed two tools: a common computer model to facilitate the sharing of daily water operations data; and a clear, written description of existing procedures by which the river has come to be managed. A long-term planning version of the Upper Rio Grande Water Operations Model (URGWOM) and a specific set of written operating rules and coordination procedures for the alternative selected in the Record(s) of Decision are the outcomes of this project.

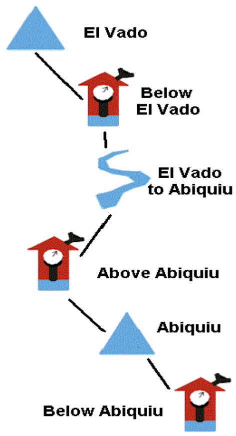
The Action Alternatives developed in the Water Operations Review (Review) and Environmental Impact Statement (EIS) are integrated water operations plans for federally-operated facilities in the upper Rio Grande basin. In the past, these facilities operated with limited coordination and consideration of the long-term cumulative impacts to natural and human resources. Each alternative presents a specific set of limits for operations developed from a study of flexibilities within existing authorities for federal facilities in the upper Rio Grande basin, as well as consideration of public comments during scoping. The Preferred Alternative was selected on the basis of the combined positive benefits it would afford for the affected resources in the basin. Operations that could potentially provide positive benefits, but were not evaluated because they are outside the existing authorities of the joint lead agencies (JLA), are discussed in Chapter 6, Section 6.2.

This project is a cooperative process involving multidisciplinary and multi-agency teams who did the work, shared resources to collect new data, shared data collected by others, provided multi-agency project management, collaborated in multi-agency tool development and use, and cooperated in many other ways. The JLA strove to disclose and describe how water management agencies operate, to improve communication between agencies, to foster better coordination with the tribes, and to increase interaction with the public with respect to water operations in the upper Rio Grande basin.

In addition, the Review and EIS stand as a foundation for future research, planning, and management (see Appendix Q). This project documents what we know about the upper Rio Grande basin, points out much of what we do not know, and identifies areas where more work needs to be done.

2.2 Key Tools

Given the complexity of the Review, numerous tools were refined and developed for use in the evaluation of alternatives. These key tools are briefly described in this section. More detailed descriptions are available in the specified referenced appendices. These tools include URGWOM, FLO-2D model, RMA-2/Aquatic Habitat Model, the San Acacia Surface Water/Groundwater Model, GIS spatial analysis and data, described individually below. The 40-year hydrologic modeling sequence represents the range of climatic conditions used to evaluate the effects of alternatives. In addition, a decision support model was used to aid in comparing and contrasting results of the alternatives. This suite of tools provides the best available information concerning the Rio Grande system.



2.2.1 URGWOM Planning Version

The URGWOM planning version represents the framework of the institutionally and physically complex upper Rio Grande system. URGWOM is a set of daily time-step, river-reservoir models for the basin using RiverWare® software. The model was used to simulate river hydrographs and reservoir contents for the No Action Alternative and the Action Alternatives to compare their effects on river and reservoir conditions over a range of hydrologic conditions, from drought to wet periods. The cartoon to the left shows an example of the URGWOM workspace reservoir, reach, and gage objects. Additional information on the use of the URGWOM planning version is presented in Appendix I. Complete draft documentation of all URGWOM versions is available on the website at http://www.spa02.usace.army.mil/urgwom.

2.2.2 Stochastic 40-Year Hydrologic Sequence

The years from 1975 through 2000 included an unusually wet period that is not representative of the long-term climate record reflected in direct measurements over the past century and paleoclimate records (see Appendix I for details). To better represent a future 40-year planning period, daily water data for the years from 1975 to 2000 were analyzed and sampled to randomly generate a 40-year sequence of data more representative of long-term conditions. This sequence included a wet period, periods drier than average, and one extreme drought period (similar to the historic drought of the 1950s). Data presented in **Figure 2-1** provided the basis for climatic inputs to URGWOM.

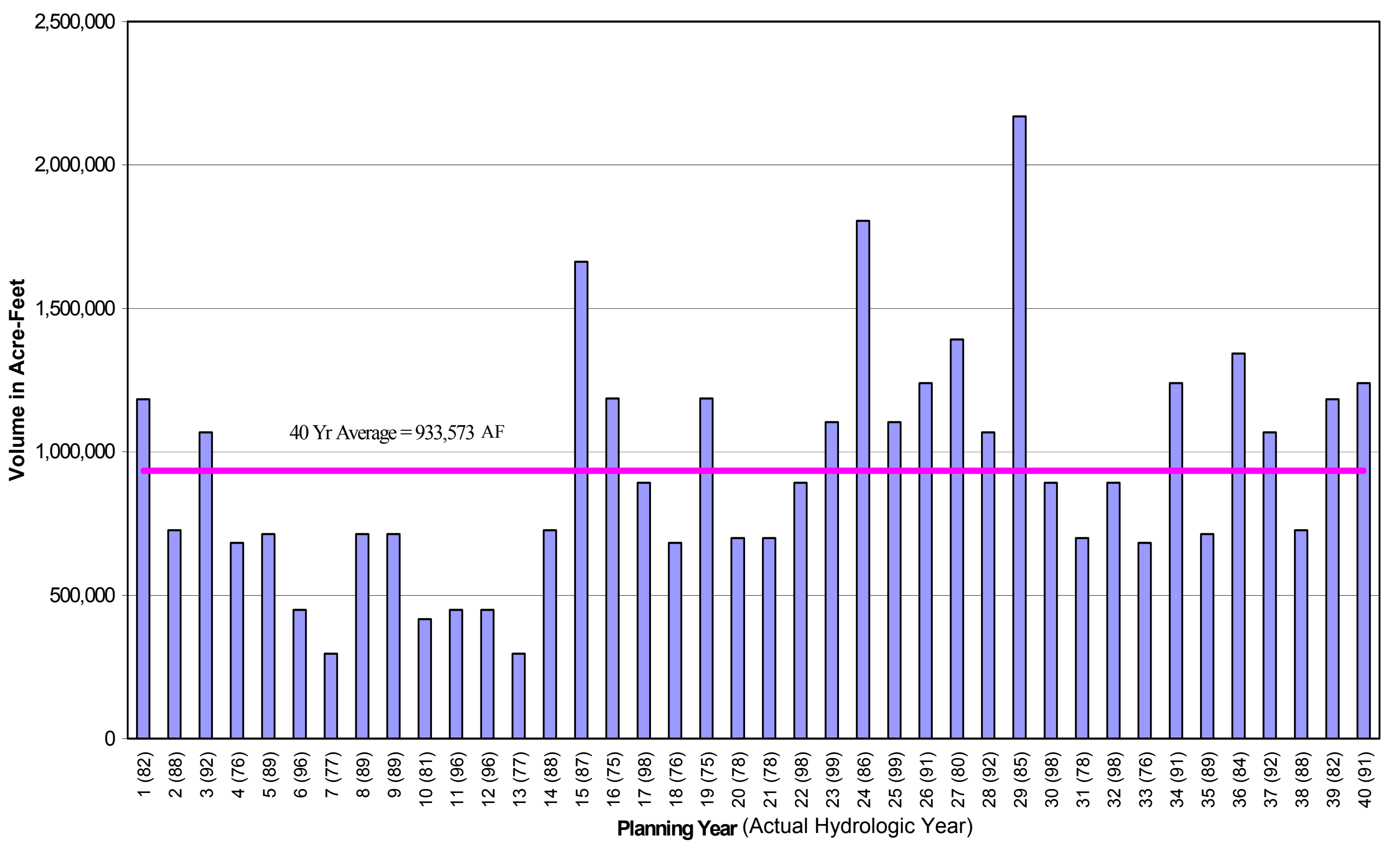
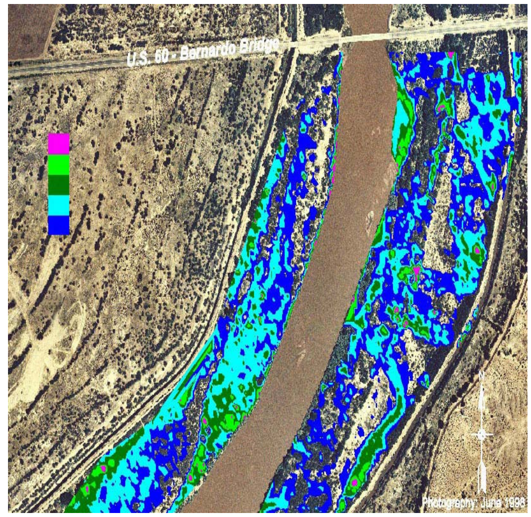


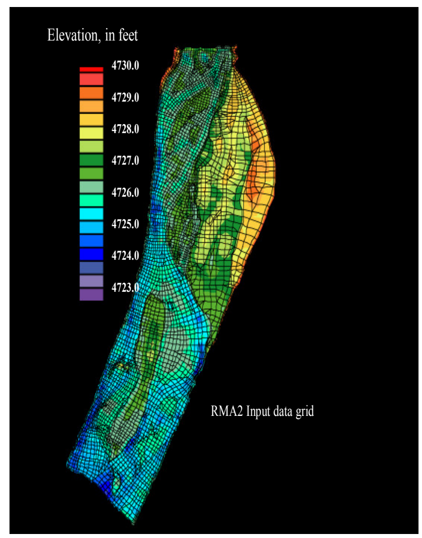
Figure 2-1. 40-Year Synthetic Hydrographic Sequence at Otowi

2.2.3 FLO-2D Hydraulic Models



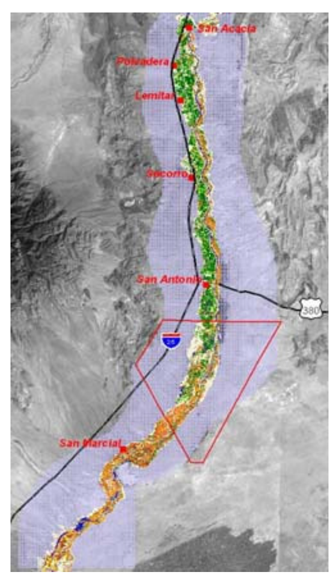
The FLO-2D model (Appendix J) is a simple volume conservation model that distributes a flood hydrograph over a system of square grid elements. It is a two-dimensional model that numerically routes a flood over a grid of surface points while predicting the area of flooding and how much the flood wave is slowed by the floodplain. The flood routing models for Reaches 7–14 (Appendix J) were developed in cooperation with many agencies in the upper Rio Grande basin to provide a basis for determining overbank flooding. The Review and EIS used these models to assist in understanding the differences in hydraulic effects between action alternatives. These models helped translate the flows from URGWOM into depths, velocities, and the extent and duration of inundation and estimated sediment transport. An example of overbank flooding areas generated by FLO-2D is shown to the right.

2.2.4 RMA-2 Hydraulic Model/Aquatic Habitat Model



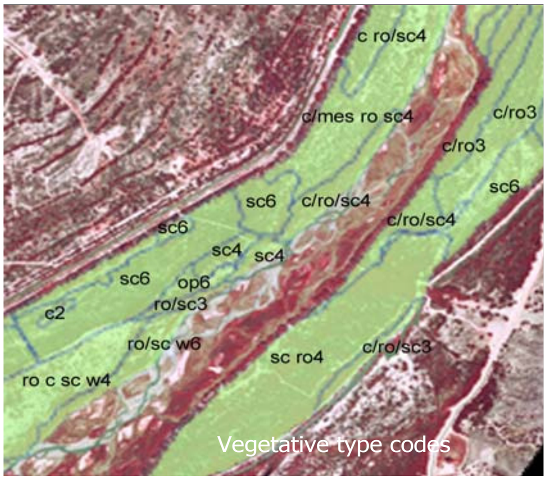
RMA-2 is a two-dimensional module for a surface modeling system developed at Brigham Young University in cooperation with the Corps Waterways Experiment Station. RMA-2 was used to develop the hydraulic framework for each of eight representative aquatic habitat sites that provided depth and velocity information at various flows to a spreadsheet called the aquatic habitat model. This hydraulic information, combined with flow information from the URGWOM model and habitat suitability relationships developed for five fish species, comprised the Aquatic Habitat Model used to evaluate alternatives. The Hydraulic Model/Aquatic Habitat Model Development Report is included in Appendix K. A summary report on the evaluation of the alternatives with the Aquatic Habitat Model is included in Appendix K. Sample model output is shown to the right.

2.2.5 San Acacia Reach Surface Water/Ground Water Model



The NMISC developed a surface water/groundwater model of the Rio Grande reach from San Acacia to Elephant Butte reservoir (Appendix J). The purpose of the model is to evaluate potential system-wide depletions that may result from changes in operation of the Low Flow Conveyance Channel (LFCC), riparian vegetation restoration projects, and riverbed aggradation. The model simulates the Rio Grande channel, the LFCC, and the main irrigation canals and drains as well as the alluvial and the Santa Fe group aquifers. The U.S. Geological Survey program MODBRANCH is used to represent the surface water/groundwater system. The surface water component is represented by solving the one-dimensional form of the continuity and momentum equations, known as Saint-Venant equation. The groundwater component is dynamically linked to the surface water component. The physical processes represented in the model are surface water routing, surface water/ groundwater interaction, discharge from springs, riparian and crop depletions, groundwater withdrawals and groundwater levels. The model provides groundwater elevation, surface water flow and riparian and crop depletion. The area shown to the right is the extent of this model.

2.2.6 Geographic Information System (GIS) Spatial Analysis



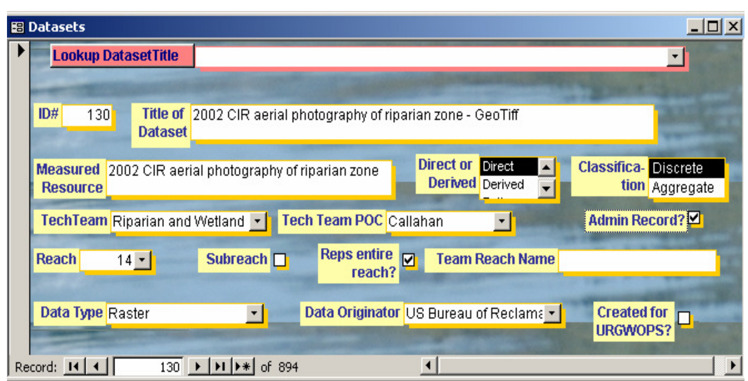
A basin-wide system was developed for geospatial analysis, data integration across resources, and referencing data points to specific geographic locations. Geographic Information System (GIS) software was used in the project as the basis for managing and sharing data throughout the lifecycle of this EIS for data collection, organization, evaluation, analysis, and synthesis. GIS analysis was used to process spatial outputs from the key tools, associated databases, and other sources in order to characterize the affected environment and analyze impacts of the EIS alternatives. Data generated from GIS were tabular, spatial, or a combination. An example of vegetation mapping developed for this project is shown to the left.

2.2.7 Decision Support System

Criterium Decision Plus™ (InfoHarvest 2001) is used to document a multicriteria decision-making process leading to the selection of a preferred alternative that best meets weighted decision criteria. The model uses decision criteria, weights assigned by decision-makers and stakeholders, and alternative performance rankings to identify the highest ranking alternative. The model also helps decision makers understand the values, uncertainties, and trade-offs involved in selecting a preferred alternative. See Appendix R for more details.

2.2.8 Data Quality Database

The data quality database organizes the information for each data set used in evaluation of alternatives so that it can be sorted, grouped and selected, as needed. Based on Data Query Forms filled out by each technical team, the database summarizes the data quality by reach, subject, and team. It documents, summarizes, and references data used and generated during this project. A screen print of part of the data entry form is shown to the right. Details are provided in Appendix P.



2.3 Description of No Action

2.3.1 The No Action Alternative and How It Was Derived

The No Action Alternative is the water operations alternative that depicts current storage and water delivery operations of federal facilities, including those changes in the system that are already published in the public record and will occur in the foreseeable future. It is also called the "future condition without project." For this project, it specifically means current operation of the ten water operations facilities in the basin, without integrating any of the flexibilities identified at Heron and Abiquiu Dams, Cochiti Lake, or the LFCC into a water operation plan (see Map 1-1). It does include the City of Albuquerque Drinking Water Project, assumed to be operating by year 4 of the 40-year planning period. A detailed description of the No Action Alternative is presented in Appendix I. The authorized function and current operation of each facility in the No Action Alternative is described briefly below:

- **Closed Basin Project—**Located near Alamosa, Colorado, the Reclamation's Closed Basin Project uses wells to salvage groundwater from high water table conditions to assist Colorado in meeting its Rio Grande Compact delivery obligations. Some of the salvaged water is also used to support the Alamosa National Wildlife Refuge, the Blanca Wildlife Habitat Area, and support wildlife and recreational facilities at San Luis Lake. Salvaged groundwater varies in quality and is therefore blended to meet quality requirements of the Rio Grande Compact and the Clean Water Act. A network of observation wells monitors water levels in the underlying confined and unconfined aquifers to ensure that operations are within drawdown limits prescribed by the authorizing legislation. Well degradation and fouling is now limiting production. A well rehabilitation and replacement program is in progress. *There would be no changes in the current operation of the Closed Basin Project under the No Action Alternative nor under any of the Action Alternatives.*
- **Platoro Dam—**Also in Colorado, Platoro Dam on the Conejos River is a Reclamation facility operated by the Conejos Water Conservancy District. A joint-use pool is used for both flood space and conservation; if flood space is needed, water in conservation storage is released to make room. A small permanent pool is maintained for recreation, fish, and wildlife, and Platoro is managed to preserve fish and wildlife downstream. Flood control operation is the responsibility of the U.S. Army Corps of Engineers (Corps) and is the only function under review under the scope of this project. Because Platoro is a post-1929 reservoir, its operations are subject to Compact requirements. *There would be no changes in the operation of Platoro under the No Action Alternative nor under any of the Action Alternatives.*
- **Heron Dam**—Heron Dam on Willow Creek in northern New Mexico stores no native Rio Grande water, therefore, this reservoir is not subject to Compact requirements. It was built by Reclamation in the late 1960s to store water from the upper Colorado River system and to import it to the Rio Grande through the San Juan-Chama (SJC) Project. There are maximum limits on transbasin deliveries in any one year and in any ten-year period. Reclamation stores water in Heron Reservoir to meet the demands of its SJC Project water contractors who are required to take delivery of their annual allotment by December 31 of the irrigation year. Carryover storage is not permitted, except by waiver. *The No Action Alternative waiver delivery date would be April 30.*
- **El Vado Dam—**Next in the sequence of facilities on the upper Rio Grande is El Vado Dam on the Rio Chama. This reservoir was not part of the Review due to active litigation and changes to its operations were not considered. *Historic operation of the facility was modeled in evaluating the No Action and all of the Action Alternatives.*
- **Abiquiu Dam—**Abiquiu Dam, also on the Rio Chama, is operated as a flood control facility by the Corps. During flood control operations, water is released at a rate of up to 1,800 cubic feet per second (cfs) to evacuate the reservoir and maintain safe channel capacity downstream. The reservoir can also be used to store SJC Project water up to an elevation of 6,220 feet. The City of Albuquerque owns storage easements up to this elevation and has a current contract with the Corps to store SJC Project water in this incidental pool. The reservoir is also authorized to store native Rio Grande water in the authorized SJC Project water space when such space is not needed. Such storage is subject to other requirements such as a state engineer permit, a Corps deviation from normal operations, and unanimous concurrence of the deviation by the Compact

Commission. *The No Action Alternative would maintain a channel capacity downstream of Abiquiu Dam of 1,800 cfs and would not store native Rio Grande water in the reservoir.*

- **Cochiti Dam—**Cochiti Dam, operated by the Corps, is a sediment and flood control structure located primarily on Pueblo of Cochiti lands. Pueblo of Cochiti has provided most of the lands, easements and rights-of-way for the facility and the Corps coordinates with Pueblo of Cochiti on actions involving this reservoir. Cochiti Dam spans the main stem of the Rio Grande and the Santa Fe River tributary to the Rio Grande, south of Santa Fe, New Mexico, on the Pueblo of Cochiti. The Corps has specific requirements for holding and releasing carry-over native Rio Grande floodwater in the facility. A permanent pool of SJC Project water is maintained in Cochiti Lake for recreation, fish, and wildlife. There is no authorization to store native Rio Grande water in Cochiti Lake. *The No Action Alternative would maintain a downstream channel capacity for flood control releases of 7,000 cfs, as measured at the Albuquerque gage.*
- **Jemez Canyon Dam—**A sediment and flood control structure on the Rio Jemez, Jemez Canyon Dam is operated as a dry reservoir by the Corps. The dam and reservoir area are on Pueblo of Santa Ana lands and the Corps coordinates with the Pueblo on actions involving this reservoir. There are no water contracts in place or proposed for re-establishing a sediment pool. *The No Action Alternative would continue to operate Jemez Canyon Dam as a dry reservoir.*
- **Low Flow Conveyance Channel—**The LFCC was constructed by Reclamation in the 1950s to aid delivery of Compact waters to Elephant Butte Reservoir. It also served to improve drainage and supplement irrigation water supply. The riprap-lined channel parallels an approximately 60-mile reach in the San Acacia Section of the Rio Grande from San Acacia to San Marcial, New Mexico. The LFCC collects river seepage and irrigation surface and subsurface return flows; transport via the LFCC reduces evaporation, as shown in **Figure 2-2**. The usefulness of the LFCC is somewhat determined by the water level of Elephant Butte Reservoir. When outfall conditions allow, up to 2,000 cfs can be diverted into the LFCC at San Acacia. The facility also provides water to both Bosque del Apache National Wildlife Refuge and to irrigators in the Middle Rio Grande Conservancy District. *This alternative preserves the authorization and flexibility to divert up to 2,000 cfs, if necessary to meet downstream obligations. However, the current physical condition of the LFCC precludes active diversion since high water levels in Elephant Butte buried the last 15 miles of the channel and outfall in the late 1980s.*
- **Elephant Butte Dam—**Elephant Butte Reservoir is owned and operated by Reclamation, and is the primary water storage facility for Rio Grande Project water. Rio Grande Project water is delivered primarily to New Mexican, Texan, and Mexican irrigators living downstream of Caballo Reservoir. Release of water for delivery to the downstream entities was not addressed in the Review and EIS. Operation of the facilities for "prudent flood space" was included in the scope of this Review and EIS. A 50,000 acre-foot (AF) flood space is maintained from April 1 to September 30; 25,000 AF of flood space is reserved between October 1 and March 31. Flood release is required when the reservoir level is within the prudent flood space. Generation of hydropower is a secondary purpose of the facility. *The No Action Alternative and all of the Action Alternatives would include the same written coordinated procedures and protocol on how Reclamation and the Corps will work together when circumstances warrant use of the "prudent flood space."* Elephant Butte Dam and Caballo flood control protocol are documented in Appendix I.

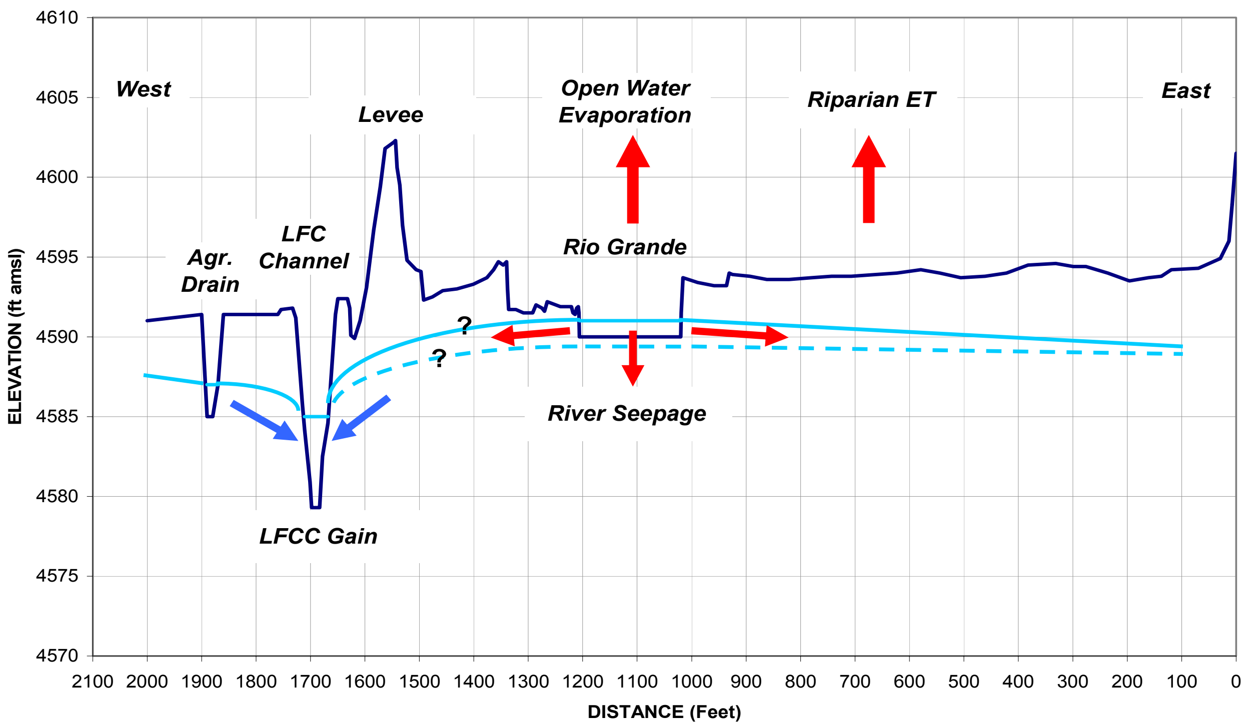


Figure 2-2. Floodplain Cross-Section of Rio Grande and Low Flow Conveyance Channel near Socorro

- **Caballo Dam**—Caballo Dam is similar to Elephant Butte, and only flood control activities were part of the Review and Water Operations EIS. Reclamation constructed Caballo and coordinates flood control operations with the U.S. Section of the International Boundary and Water Commission (USIBWC). Protocol for flood operations involving the Corps operation of Cochiti Dam for certain flooding conditions downstream of Caballo was developed and coordinated among the USIBWC, Reclamation, and the Corps as part of the Review. *The No Action Alternative and all of the Action Alternatives would include the documentation of the circumstances and protocol for how the USIBWC, Reclamation, and the Corps will work together when it is necessary to hold back floodwaters in Cochiti to prevent flooding below Caballo.* Elephant Butte and Caballo flood control protocol are documented in Appendix I.

2.4 Description of Action Alternatives

The development and description of the alternatives are described in CEQ Regulations for Implementing NEPA, Section 1502.14, as "the heart of the environmental impact statement." Alternatives other than the No Action Alternative may be developed to meet the purpose and need and in response to substantive scoping comments, in order to evaluate a range of reasonable alternatives. This section identifies the issues and process used to develop the alternatives analyzed in detail in this EIS, as well as those alternatives eliminated from detailed study.

2.4.1 Significant Issues Identified During Scoping

General actions to coordinate and improve facility operations were published in the March 2000 Notice of Intent to conduct the EIS (FR 2000). The JLA held nine scoping meetings in 2000 in Colorado, New Mexico, and Texas to identify issues of concern and to further define the range of flexibilities to be considered in this EIS. Meeting attendees expressed an interest in learning more about the alternatives before they were finalized and analyzed. In response, the JLA held an additional 10 meetings in 2002 to present draft alternatives and proposed operational changes, and to clarify issues of importance to the public that needed to be addressed in the action alternatives. The comments from the second round of public meetings can be considered an extension of scoping. Full comment text from the draft alternatives public meetings is provided in Appendix E. Possible operational flexibilities presented by the JLA at the meetings identified ranges to be considered for reservoir storage and channel capacity, flow bypasses, and timing of waivers. Also discussed for background information were uncertainties in weather, variability in runoff, and unplanned issues affecting water management. Significant comments identified by the public in the alternatives development meetings that were determined to be relevant for developing the Action Alternatives are summarized briefly below under primary categories. Many comments submitted were appropriate to be considered in the effects analyses for specific resources. Although they do not appear below, they are addressed in Chapter 4, Environmental Consequences.

1. Water Operations/Reservoirs/River Flows
    a. Consider lower than current Rio Chama channel flows below Abiquiu Dam.
    b. Identification of additional upstream storage capacity to minimize evaporation losses.
    c. Store water upstream as long as possible by changing the timing of releases.
2. Threatened and Endangered Species: Examine the flexibility in the system related to timing releases to manage for threatened and endangered species.
3. Agriculture: Consider lower flows than currently in the channel below Abiquiu Dam in order to protect Rio Chama acequia headgates and diversion structures.

After the public meetings and input from the JLA, water managers, Cooperating Agencies, and other stakeholders, seven combinations of water operations were developed. These operational variations included: varying waiver dates at Heron Reservoir; varying native storage at Abiquiu Reservoir; varying channel capacities below Abiquiu and Cochiti Dams; a range in diversion to the LFCC; and improved flood control protocols and coordination at Elephant Butte and Caballo Dams. Additional information concerning the public scoping process and input received is included in Chapter 5 and Appendix E.

2.4.2 Description of Alternatives for Detailed Analysis

Based on public scoping, review of historic hydrologic extremes, and considering the breadth of possible events that could occur within a 40-year planning period, draft operational plans (designated by letters) were developed using combinations of facility-specific actions. These plans were further differentiated (modified by numbers) recognizing natural limitations and operational feasibilities under a range of climatic conditions. Some draft alternatives necessarily fell out in the initial screening process through application of the three preliminary screening criteria presented in the public scoping meetings: (1) the alternative is physically possible; (2) the alternative meets the Memorandum of Agreement purpose and need statement; and (3) the alternative is within the existing authorities of the agencies involved.

Alternatives considered for detailed analysis were selected based on a review of preliminary URGWOM planning version results using three threshold screening criteria identified by the JLA and Steering Committee, together with detailed water operations performance measures developed by the Water Operations Support Team and consideration of significant issues identified by the public in the draft alternatives meetings. Threshold criteria included dam safety and flood control operations, Compact compliance, and meeting contractual water supply obligations. The final alternatives that were analyzed in this EIS are listed in **Table 2-1** with the primary operational components at each facility that were identified as having flexibility.

Table 2-1. Summary of No Action and Action Alternatives Retained for Detailed Analysis

Alternatives	Operation/Facility						
	Heron Waivers	Abiquiu Storage Capacity	Abiquiu Channel Capacity	Cochiti Channel Capacity	Diversions to LFCC	Elephant Butte and Caballo	Basin-wide
No Action [1] (G-3)	April 30	0 AF	1,800 cfs	7,000 cfs	0–2,000 cfs	Informal coordination	Informal communication
B-3	Sept. 30	0–180,000 AF	1,500 cfs	8,500 cfs	No Change	Protocol/ coordination	Improved communications
D-3	Aug. 31	0–180,000 AF	2,000 cfs	No Change	No Change	Protocol/ coordination	Improved communications
E-3 [2]	Sept. 30	0–180,000 AF	No Change	10,000 cfs	No Change	Protocol/ coordination	Improved communications
I-1	No Change	0–20,000 AF	No Change	No Change	0–500 cfs	Protocol/ coordination	Improved communications
I-2	No Change	0–75,000 AF	No Change	No Change	0–1,000 cfs	Protocol/ coordination	Improved communications
I-3	No Change	0–180,000 AF	No Change	No Change	No Change	Protocol/ coordination	Improved communications

Note: No Change means no difference from No Action alternative. Modeled diversions to the LFCC begin only when there is at least 250 cfs in the river.

[1] Least flexible alternative. [2] Most flexible alternative.

A brief description of how the Action Alternatives are different from the No Action is included below, associated with the numbers of the significant issues to which they respond. Several of the alternatives address the same public comments, but vary in a few parameters in order to facilitate the evaluation of resource impacts from combinations of differences throughout the system. Alternatives were modeled to maximize available storage and diversion capacities.

2.4.2.1 Alternative B-3

Alternative B-3 was defined as an Action Alternative in order to evaluate the impacts of later water delivery from Heron Dam, to take advantage of the flexibility available to store native Rio Grande water in Abiquiu Reservoir, consider lower flows below Abiquiu Dam, and higher flows below Cochiti Dam. These variations from No Action were included in an alternative to address the following issues identified in Section 2.4.1 above: 1a, 1b, 1c, 2, and 3.

2.4.2.2 Alternative D-3

The primary differences between Alternative D-3 and the No Action Alternative are a later Heron waiver date, storage of native Rio Grande water in Abiquiu Reservoir, and a higher maximum flow below Abiquiu Dam. These variations from No Action were included in an alternative to address the following issues identified in Section 2.4.1 above: 1b, 1c, 2.

2.4.2.3 Alternative E-3

The primary differences between Alternative E-3 and the No Action Alternative are a later Heron waiver date, storage of native Rio Grande water in Abiquiu Reservoir, and a higher maximum flow in the channels below Abiquiu Dam and Cochiti Dam. These variations from No Action were included in an alternative to address the following issues identified in Section 2.4.1 above: 1b, 1c, 2.

2.4.2.4 Alternative I-1

The primary differences between Alternative I-1 and the No Action Alternative are storage of native Rio Grande water in Abiquiu Reservoir and a lower maximum diversion into the LFCC. These variations from No Action were included in an alternative to address concerns from the Interdisciplinary NEPA Team that a greater range of upstream storage and LFCC diversions should be analyzed in order to better understand the impacts to resources along the Rio Chama and the Rio Grande. It was also developed to increase the variation between alternatives in compliance with NEPA requirements.

2.4.2.5 Alternative I-2

The primary differences between Alternative I-2 and the No Action Alternative are storage of native Rio Grande water in Abiquiu Reservoir and a lower maximum diversion into the LFCC. These variations from No Action were included in an alternative to address concerns from the Interdisciplinary NEPA Team that a greater range of upstream storage and LFCC diversions should be analyzed in order to better understand the impacts on resources along the Rio Chama and the Rio Grande. It was also developed to increase the variation between alternatives in compliance with NEPA requirements.

2.4.2.6 Alternative I-3

The primary differences between Alternative I-3 and the No Action Alternative are high amounts of storage of native Rio Grande water in Abiquiu Reservoir and the maximum authorized diversion into the LFCC. These variations from No Action were included in an alternative to analyze the impacts to the system through exercising maximum flexibility in upstream storage and LFCC diversions in order to better understand the impacts on resources along the Rio Chama and the Rio Grande.

2.4.3 Description of Operational Flexibilities and Preliminary Screening

The scope of this Review and EIS was limited to evaluating operational flexibilities in ten water operations facilities under existing JLA authorities. Of the ten facilities, only El Vado Dam was determined to be outside the scope of this Review and EIS. The nine remaining facilities can be manipulated individually or in concert by the lead federal agencies to address various situations. First, general areas of flexibility were identified:

- **Heron Reservoir Waivers—**A waiver provides an extension for water contractors required to take delivery of their current-year SJC water allocation from Heron Reservoir before December 31. Waivers are typically not provided unless they would benefit the federal government and would not interfere with other water users. Contractors take delivery upon release by the use, sale, or movement of water to downstream storage reservoirs. Extending waiver dates can allow for additional storage of native water downstream. Temporary waivers allowing extended storage and later delivery were historically used to enhance winter flows and fisheries management on the Rio Chama. Waivers provide additional capacity to store snowmelt runoff and SJC waters in other downstream reservoirs, as long as Compact compliance is maintained. Waivers are only permitted for SJC water stored in Heron Reservoir.
- **Abiquiu Reservoir Native Storage—**Currently, Abiquiu Reservoir is the only facility above San Marcial (approximately 237 river miles upstream) authorized for native storage. Opportunities for native water storage in Abiquiu Reservoir occur, subject to a State Engineer permit, when all of the following are true.
    1. Native water flow on the mainstem of the Rio Grande is sufficient to meet downstream demand in the Española and middle Rio Grande valleys.
    2. Native water inflow to the reservoir exceeds downstream demand on the Rio Chama.

3. Rio Grande Compact does not limit native water storage operations.
4. New Mexico is in an accrued Compact credit status.
5. Space exists in the authorized pool within the reservoir.

- **Channel Capacity—**Ranges in channel capacity downstream of Abiquiu and Cochiti Dams offer options to decrease or increase release rates in accordance with needs for flood management, water delivery demands, and Compact compliance.
- **LFCC Operations—**Historically, the LFCC conveyed water from San Acacia to Elephant Butte Reservoir, reducing evaporation, transpiration, and infiltration losses, resulting in improved Compact compliance. While the LFCC is not currently operational, as designed, Reclamation is evaluating a full range of operations including realigning and restoring this conveyance and diversion at original design diversion rates, diversion at limited rates, and zero diversions. This EIS considers the full range of diversion options for the LFCC.

No substantive operational flexibilities were identified for the Closed Basin Project and Platoro Dam. Only limited changes were identified for Elephant Butte and Caballo Reservoirs because only flood control operations were included for consideration in this Review and EIS.

2.4.4 Considered but Eliminated from Detailed Analysis

A complete list of all of the draft alternatives developed for preliminary analysis, including those selected to be analyzed in detail, appears in **Table 2-2**. Appendix I documents the actions considered at each facility and the water operations attributes used to evaluate each action. The rationale for selecting or not selecting an action is also presented in detail. Plans A through F were developed considering the ranges of operating flexibility at each facility, together with scoping issues. Plan G represents present operating conditions with improved coordination and communication and was identified as the No Action Alternative. Plan H represents historic independent facility operations by various federal agencies. Plan I Alternatives were added based on additional constraints requested for further consideration by the Interdisciplinary (ID) National Environmental Policy Act (NEPA) Team in order to ensure that a full range of alternatives would be considered. Actions determined to be outside the scope of this Review and EIS are discussed in Chapter 6 for possible future consideration.

To assist in the selection of the Action Alternatives and the elimination of some of the draft alternatives, ten qualitative performance criteria were established and weighed in importance, as shown in **Table 2-3**. The Water Operations Team evaluated the relative magnitude of flood control protection, Compact delivery, native storage, carryover storage, reservoir drawdown, peak flow, sediment transport, and water supply delivery. Alternative performance against the ten performance measures was assessed and ranked. Action alternatives were selected for further analysis. The alternatives selected provided a high level of flexibility and maintained the ability to balance variable water supply conditions with multiple demands. The highest-ranking alternatives included Plans B-3, C-3, D-3, E-3, and I-3. The ID NEPA Team also requested the inclusion of two alternatives. To limit the number of alternatives analyzed in detail, Action Alternatives C-3 and E-3 were combined due to similarities in proposed actions. Although Alternatives I-1 and I-2 do not necessarily meet the Rio Grande Compact compliance threshold criterion, they were retained at the request of the Interdisciplinary NEPA Team to broaden the spectrum of alternatives analyzed to include limiting LFCC diversions and restrictions on Abiquiu native water storage. Alternatives retained for detailed analysis are highlighted in Table 2-2. Alternative scores relative to performance measures evaluated by the Water Operations team are presented in Table 2-3.

Table 2-2. Alternative Plans Considered for Analysis

Plan	A	B	C	D	E	F	G	H	I
Feature or Action	**A-1**	**B-1**	**C-1**	**D-1**	**E-1**	**F-1**	**G-1**		**I-1**
Heron Reservoir Waivers	Waivers - 4/30	Waivers - 4/30	Waivers - 4/30	Waivers - 4/30	Waivers - 4/30	Waivers - 4/30	NC	NC	Waivers - 4/30
Abiquiu Native Storage	0-20,000 AF	0-20,000 AF	0-20,000 AF	0-20,000 AF	0-20,000 AF	0 AF	NC	NC	0-20,000 AF
Abiquiu Channel Capacity	1,200 cfs	1,500 cfs	1,800 cfs	2,000 cfs	1,800 cfs	1,800 cfs	NC	NC	1,800 cfs
Cochiti Channel Capacity	7,000 cfs	7,000 cfs	7,000 cfs	7,000 cfs	10,000 cfs	10,000 cfs	NC	NC	7,000 cfs
Low Flow Conveyance Channel	0 - 2,000 cfs	0 - 2,000 cfs	0 - 2,000 cfs	0 - 2,000 cfs	0 - 2,000 cfs	Limited Diversion	NC	NC	0 - 500 cfs
Elephant Butte/Caballo Coordination	I	I	I	I	I	I	I	NC	I
Communications	I	I	I	I	I	I	I	NC	I
Feature or Action	**A-2**	**B-2**	**C-2**	**D-2**	**E-2**	**F-2**	**G-2**		**I-2**
Heron Reservoir Waivers	Waivers - 9/30	Waivers - 9/30	Waivers - 9/30	Waivers - 8/31	Waivers - 4/30	Waivers - 4/30	NC	NC	Waivers - 4/30
Abiquiu Native Storage	20,000-75,000 AF	20,000-75,000 AF	20,000-75,000 AF	20,000-75,000 AF	20,000-75,000 AF	0 AF	NC	NC	0-75,000 AF
Abiquiu Channel Capacity	1,200 cfs	1,500 cfs	1,800 cfs	2,000 cfs	1,800 cfs	1,800 cfs	NC	NC	1,800 cfs
Cochiti Channel Capacity	7,000 cfs	7,000 cfs	7,000 - 10,000 cfs	7,000 cfs	10,000 cfs	10,000 cfs	NC	NC	7,000 cfs
Low Flow Conveyance Channel	0 - 2,000 cfs	0 - 2,000 cfs	0 - 2,000 cfs	0 - 2,000 cfs	0 - 2,000 cfs	Coordination & Protocol	NC	NC	0 - 1,000 cfs
Elephant Butte/Caballo Coordination	I	I	I	I	I	I	I	NC	I
Communications	I	I	I	I	I	I	I	NC	I

Plan	A	B	C	D	E	F	G	H	I
Feature or Action	**A-3**	**B-3**	**C-3*** **	**D-3**	**E-3**	**F-3**	**G-3 (No Action)**		**I-3**
Heron Reservoir Waivers	Waivers - 9/30	Waivers - 9/30	Waivers - 9/30	Waivers - 8/31	Waivers - 4/30	Waivers - 4/30	NC	NC	Waivers - 4/30
Abiquiu Native Storage	75,000-180,000 AF	0-180,000 AF	75,000-180,000 AF	0-180,000 AF	0-180,000 AF	0 AF	NC	NC	0-180,000 AF
Abiquiu Channel Capacity	1,200 cfs	1,500 cfs	1,800 cfs	2,000 cfs	1,800 cfs	1,800 cfs	NC	NC	1,800 cfs
Cochiti Channel Capacity	7,000 - 8,500 cfs	8,500 cfs	8,000 - 10,000 cfs	7,000 cfs	10,000 cfs	10,000 cfs	NC	NC	7,000 cfs
Low Flow Conveyance Channel	0 - 2,000 cfs	0 - 2,000 cfs	0 - 2,000 cfs	0 - 2,000 cfs	0 - 2,000 cfs	Coordination & Protocol	NC	NC	0 - 2,000 cfs
Elephant Butte/Caballo Coordination	I	I	I	I	I	I	I	NC	I
Communications	I	I	I	I	I	I	I	NC	I

NOTES:

(black box)	Denotes alternative retained for detailed analysis	AF = acre-feet	Waivers - #/# = Waivers - month/day
NC	No change from current operations	cfs = cubic feet per second	C-3*** = Alternative combined with E-3 for detailed analysis
I	Improved communications		

Table 2-3. Decision Support: Alternative Performance vs. Water Operations Performance Measures

	Performance Measure	Compatible w/Flood Control Operations	Compatible w/Rio Grande Compact	Improves System Operational Flexibility	Supports Water Delivery	Maximizes Conservation Storage Opportunities	Maximizes Peak Discharge Opportunities	Maximizes Sediment Transport Opportunities	Supports Desirable Winter Flows	Supports Recreational Uses	Supports Stable Reservoir Levels		
	Threshold Criterion	X	X		X								
	ALTERNATIVE / Weight	0.20	0.20	0.15	0.15	0.10	0.08	0.05	0.04	0.02	0.01	Wtd. Avg. % Met	Rank
1	**Plan G - No Action (Baseline)**	**7**	**4**	**5**	**8**	**0**	**6**	**6**	**5**	**5**	**5**	**52.80%**	**19**
2	Plan A-1	4	5	3	2	3	2	2	3	3	3	33.20%	22
3	Plan A-2	4	5	4	2	7	2	2	1	1	1	37.30%	21
4	Plan A-3	4	5	5	2	10	2	2	1	1	1	41.80%	20
5	Plan B-1	6	7	6	7	3	5	5	4	4	4	57.80%	18
6	Plan B-2	7	7	8	8	7	7	7	5	5	5	71.60%	16
7*	**Plan B-3**	**9**	**9**	**10**	**8**	**10**	**8**	**9**	**5**	**5**	**5**	**87.40%**	**6**
8	Plan C-1	7	8	6	8	3	6	6	5	5	5	65.30%	17
9	Plan C-2	10	10	8	9	7	9	8	6	5	5	87.60%	5
10***	**Plan C-3**	**10**	**10**	**10**	**10**	**10**	**9**	**9**	**6**	**5**	**5**	**95.60%**	**1**
11	Plan D-1	10	8	7	10	3	8	8	5	5	5	78.40%	11
12	Plan D-2	10	8	8	10	7	8	8	5	5	5	83.90%	8
2*	**Plan D-3**	**10**	**10**	**10**	**10**	**10**	**8**	**8**	**5**	**5**	**5**	**93.90%**	**3**
14	Plan E-1	10	10	6	8	3	9	9	5	6	5	79.40%	10
15	Plan E-2	10	10	7	9	7	9	9	6	6	5	86.80%	7
16*	**Plan E-3**	**10**	**10**	**9**	**10**	**10**	**9**	**9**	**6**	**6**	**5**	**94.30%**	**2**
17	Plan F-1	10	8	5	10	0	9	9	6	6	6	74.40%	13
18	Plan F-2	10	8	5	10	0	9	9	6	6	6	74.40%	13
19	Plan F-3	10	8	5	10	0	9	9	6	6	6	74.40%	13
20**	**Plan I-1**	**10**	**6**	**6**	**10**	**3**	**7**	**7**	**6**	**6**	**6**	**72.30%**	**15**
21**	**Plan I-2**	**10**	**8**	**8**	**10**	**7**	**7**	**7**	**6**	**6**	**6**	**83.30%**	**9**
22*	**Plan I-3**	**10**	**10**	**10**	**10**	**10**	**7**	**7**	**6**	**6**	**6**	**93.30%**	**4**

NOTES: 1. Performance Measure weights sum to 100 points total
2. Weighted Average Percent Met multiplies sums (scores * weights) for all measures
3. Alternatives are ranked from highest to lowest score
4. Alternatives selected for detailed analysis are shown in bold text.

7*	Alternative Selected by Water Operations Rankings for Detailed Analysis
20**	Alternative Selected by ID NEPA Team for Broader Operations Analysis
10***	Alternative combined with E-3 for detailed analysis

General reasons why certain alternatives moved forward, while others were eliminated from further analysis, are summarized below (Appendix I). This analysis is partly based on an evaluation of discrete operational elements.

- **Heron Reservoir Waiver Flexibility (April 30, June 30, August 31, September 30, and No Waivers)—**Waivers extending carryover deadlines expand operational flexibility. April 30 waivers reflect current operating policy that benefits the United States, SJC Project contractors, and affords winter flows on the Rio Chama between El Vado Dam and Abiquiu Reservoir. The June 30 waiver option was not considered further because it did not provide significant benefit over the current April 30 waiver allowance and encumbered possible early snowmelt storage during the March to May time frame. The August 31 extension for carryover storage was retained for further analysis because it offered the potential to increase system-wide water storage in downstream reservoirs (El Vado or Abiquiu Reservoirs). SJC water subject to an August 31 waiver would be delivered in July and August, after snowmelt runoff. In most years, there is demand for native water in storage by late June; native water released from storage would be replaced by the release of waivered SJC water stored in Heron Reservoir. The September 30 waiver provides an additional month of flexibility over the August 31 option and was retained for analysis. A no waivers policy was eliminated because it restricts flexibility. Contractors who do not take delivery of SJC project water stored in Heron Reservoir, either by use, sale, or contracting for downstream storage, forfeit their allocation, which reverts back to SJC project storage. Eliminating waivers negatively impacts winter flows on the Rio Chama between El Vado Dam and Abiquiu Reservoir by restricting flows to only that amount required to replace water evaporated in Cochiti Lake and bypass native Rio Grande flows. Under a no waivers scenario, the Rio Chama experiences greater flow variability, being high in November and December as water is moved out of Heron Reservoir, then sharply decreasing to less than 50 cfs during January and February.
- **Abiquiu Reservoir Native Storage (20,000 AF; 75,000 AF; 180,000 AF)—**Flexibilities in storing native water in Abiquiu Reservoir were initially evaluated considering caps at 20,000; 50,000; 100,000; and 200,000 AF. To decrease the number of alternatives to be modeled,, the water operations team merged the analysis of the 50,000 and 100,000 AF storage capacities to a limit of 75,000 AF. The upper 200,000 AF native storage target was modified to 180,000 AF due to a practical storage capacity limit of 183,000 AF resulting from the sediment that has accumulated since the dam became operational. The 20,000 AF native storage option provides storage of native Rio Grande spring runoff flows in Abiquiu Reservoir in storage space not being used by SJC project water. Opportunities for additional storage occur when native flows exceed downstream demands and New Mexico is in compliance with the Compact. The maximum storage elevation of 6,220 feet mean sea level cannot be exceeded by the combination of native and SJC project water. During storage of excess native flows, release rates below Abiquiu Dam are limited to 200 cfs but can be increased to meet downstream demands. Native storage at 75,000 AF is feasible, provided space is available in the reservoir as noted above. There are a number of years where native storage could be increased to provide additional water to meet multiple demands. Therefore, the 180,000 AF practical storage limit was retained to analyze maximum potential native storage acknowledging that this limit will decrease over time due to accumulating sediment.
- **Abiquiu Channel Capacity (1,200; 1,500; 1,800; and 2,000 cfs)—**Initial evaluation of possible ranges in Abiquiu channel capacity examined 600 and 800 cfs options. However, these were eliminated prior to crafting alternatives because such low capacities could not convey sufficient water to meet Compact requirements, irrigation demands, SJC project deliveries, and maintain releases to benefit endangered species. A maximum 2,500 cfs channel capacity was also evaluated and discarded due to concerns over bank erosion, flooding, and disturbance to earthen

diversion structures. The range of channel capacities cited above was retained as a feasible series of operating ranges suitable for framing discrete alternatives.

- **Cochiti Channel Capacity (7,000; 8,500; and 10,000 cfs)—**Initial examination of a base 5,000-cfs capacity was discarded because of negative impacts to Compact deliveries, lack of channel-forming discharges, decreased flood protection, decreased overbank flooding, and limitations to SJC project deliveries. An upper 12,500 cfs maximum channel capacity was also discarded due to negative impacts from bank sloughing, possible flooding of irrigated lands in the Cochiti to Bernalillo reach, and needs for additional bank and flood protection structures. The retained channel capacities were feasible and were used in discrete alternatives subjected to further analysis.
- **LFCC Operations (0-500; 0-1,000; and 0-2,000 cfs)—**The LFCC is not currently operating due to the lack of a viable outfall to Elephant Butte Reservoir. Historically, the LFCC operations were credited with assisting the State of New Mexico in maintaining Compact compliance. If a viable outfall were constructed, the LFCC could be operated to deliver between 0 and 2,000 cfs, providing additional operating flexibility to the system. All alternatives have the potential to divert into the LFCC. Potential benefits of considering the full range of LFCC operations allows for evaluation of impacts on Compact deliveries, critical habitats, and other resources in the San Acacia Section. Improved communication and coordination was also included as federal entities have been subjected to changing flow criteria related to endangered species, as mandated by courts and legislation. While actual flow or bypass targets are subject to change, the LFCC operations were modeled assuming a 250 cfs bypass at San Acacia. The modeled 250 cfs bypass occurs only when natural river flows supply this water. Because the bypass consists of natural river flows, releases from upstream storage in order to maintain a constant 250 cfs were not modeled. Flows past San Acacia will drop below 250 cfs when there is less than 250 cfs of natural flow in the river.

2.5 Preferred Alternative

The Preferred Alternative is currently Alternative B-3, based on the cumulative resource impacts and performance relative to weighted decision criteria described in Chapters 3.0 and 4.0.

2.6 Comparison of Impacts under Each Alternative

The criteria evaluated and the impacts found for each alternative are summarized in **Table 2-4** and described in detail in Chapter 4.

Table 2-4. Comparison of Impacts under Each Alternative

Criterion/Resource	Subcategory	ALTERNATIVES						
		No Action	**B-3**	**D-3**	**E-3**	**I-1**	**I-2**	**I-3**
Dam Safety & Flood Control		Adequate	Met	Met	Met	Met	Met	Met
Water Deliveries		Adequate	Met	Met	Met	Met	Met	Met
Compact & Treaty Compliance			Met	Met	Met			Met
Ecosystem	Riverine	—	—	—	—	—	—	—
	Reservoir	—	■	■	■	■■	■■	■■
	Riparian	—	■■	■	—	❑	—	■
	T&E Species - RGSM	—	—	—	—	❑	❑	—
	T&E Species - SWFL	—	■	■■	■■	❑	—	■■
	Other T&E Species	—	■	—	—	❑	—	■
Operating Flexibility	Reservoir	—	❑❑	❑❑	❑❑	❑	❑❑	❑❑
	River	—	—	—	—	—	—	—
Water Quality		—	❑	—	—	—	—	—
Sediment Management		—	■	■	■	■	■	■
Indian Trust Assets		—	❑	■	❑	—	—	—
Cultural Resources		—	❑❑	❑❑	❑❑	❑	❑❑	❑❑
Land Use	Agricultural	—	❑❑	❑	❑	—	—	❑
	Recreation	—	❑❑❑	❑	❑❑	—	❑	❑❑
	Other Land Uses	—	❑	❑	❑	—	❑	❑
	Hydropower	—	❑	❑❑❑	❑❑❑	❑❑	❑❑	❑❑❑
	Flood Control - Damages	—	❑❑	❑❑❑	❑❑	❑	❑❑	❑❑❑
Fairness & Equity	Environmental Justice	—	❑❑	■■■	■	—	❑	■■
			TR			**EP**		

Legend:	—	No Significant Impact	T&E =	Threatened & Endangered
	❑	Slight improvement	RGSM =	Rio Grande Silvery Minnow
	❑❑	Moderate Improvement	SWFL =	Southwest Willow Flycatcher
	❑❑❑	Substantial Improvement	EP =	Environmentally-Preferred Alternative
	■	Slight Decrease	TR =	Top-Ranked Alternative
	■■	Moderate Decrease		
	■■■	Substantial Decrease		

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Chapter III

Existing Conditions in the Affected Environment

3.1 Introduction

3.1.1 Setting

Located at the western edge of the Great Plains, the Rio Grande is one of the longest rivers in the United States (U.S.) and the 24th longest in the world. It runs 1,960 miles (3,154 kilometers [km]) from its headwaters in the San Juan Mountains of southern Colorado to its terminus in the Gulf of Mexico. This Water Operations Review (Review) and Environmental Impact Statement (EIS) considers a planning area that includes the entire upper Rio Grande basin and a project area that includes the river corridors along the Rio Grande and its major tributaries from its headwaters in Colorado downstream to Fort Quitman, Texas. The affected environment is described for either the planning area or the project area, as appropriate for each resource. In this EIS, the river is discussed in terms of the following sections, reaches, and facilities shown on Map 1-1.

- **Northern Section—Rio Grande from Alamosa, Colorado, to the confluence with Rio Chama (Reaches 1 through 4 of Map 1-1)**. Water operations of the Closed Basin Project and flood control operations at Platoro Reservoir may affect this section, but no changes in operations were identified at these facilities. Flood flows in these reaches are unregulated, for the most part, except for the regulation of the Rio Conejos by Platoro Reservoir during high snowmelt runoff periods.
- **Rio Chama Section—Rio Chama to the Rio Grande confluence downstream to Cochiti Dam (Reaches 5 through 9)**. Water operations at the dams on the Rio Chama (Heron and Abiquiu) affect this section. The flood pools at Abiquiu and Cochiti Reservoirs are included and are affected by flood control operations at the dams. Flood control operations of Abiquiu and Cochiti were considered in coordination with other facilities. This section is also affected by facilities and projects outside the scope of this Review and EIS (El Vado Dam and the San Juan-Chama [SJC] Project).
- **Central Section—Cochiti Dam to the Rio Puerco confluence (Reaches 10 through 13)**. Water operations at Cochiti and Abiquiu Dams affect this section. This section may also be affected by facilities and projects outside the scope of this Review and EIS, or facilities where no changes in operation were identified (El Vado Dam, Galisteo Dam, Jemez Canyon Dam, and the SJC Project).
- **San Acacia Section—Rio Puerco confluence to Elephant Butte Dam (Reach 14)**. Water operations at Cochiti and Abiquiu Dams and the Low Flow Conveyance Channel (LFCC) affect this section. The flood pool of Elephant Butte Reservoir is also included in this section.
- **Southern Section—Elephant Butte Dam to Fort Quitman, Texas (Reaches 15 through 17)**. Flood control operations at Elephant Butte Dam and Caballo Dam and Reservoir affect this section. No changes in flood control operations at Elephant Butte Dam and Caballo Dam and Reservoir were identified and is a function of IBWC action on the Canalization Project. Other operations and facilities outside the scope of this Review and EIS may also affect this section.

3.1.2 Resources Considered

This chapter describes the resources in the existing environment that could be impacted by the Action Alternatives and the No Action Alternative. Because action alternatives only consider water operations changes at facilities in the Rio Chama, Central, and San Acacia Sections, the descriptions of the affected environment address the reaches in those sections in the most detail. The resources presented are based on a valuation of the relative importance and potential impact on the resource, as expressed by the joint lead agencies (JLA), cooperating agencies, stakeholders, and the public. Resources not affected or only minimally affected by changes identified during this Review and EIS include noise levels, air quality, hazardous materials, and seismicity. These resources are discussed only briefly at the end of this chapter. Potential measures to mitigate any impacts of changes in water operations on fish, wildlife, and other resources with statutory requirements for considering mitigation are described in Chapter 4.

3.2 Existing Hydrology and Geomorphology

The physical characteristics of natural rivers are strongly controlled by the magnitude, duration and timing of the natural, unconstrained flows that pass through them (Schumm 1977). The natural flows are in turn controlled by the climatic, geologic, and physical characteristics of the contributing watershed (Lee et al. 2004). These natural physical characteristics can be significantly altered by human activities that change infiltration and runoff patterns; that store and release water in ways that alter the natural runoff cycle and change the sediment supply; and that constrain the river to protect adjacent property from flooding and erosion. The existing form of the Rio Grande results from a combination of all of these factors. More detailed information on hydrology can be found in Appendix I and on geomorphology in Appendix H.

3.2.1 Hydrology

Natural flows in the Rio Grande system are derived from two primary sources: (1) snowmelt originating predominately from the upstream, higher elevation portions of the watershed and (2) summer thunderstorms that tend to be more localized and concentrated at lower elevations. During the past century, nearly 60 percent of the natural runoff volume in the Rio Grande at Otowi Bridge, as indicated by the Otowi Index Supply, occurred during April, May and June (**Figure 3-1**).

In the Rio Chama, about 80 percent of the natural annual flow volume occurs during April, May, and June, based on recorded flows between 1955 and 2001 at the near La Puenta gage. In contrast, runoff from lower elevation tributaries tends to occur during the monsoon season in the late summer and early fall. Nearly 80 percent of the recorded annual flow volume at the Rio Puerco near Bernardo gage occurs between July 1 and October 31, with nearly 40 percent occurring during August alone. The locations of the gages, diversions, and structures discussed in this section are shown on **Map 3-1**.

Under natural, unconstrained river conditions, the annual flow volume varies significantly from year to year, depending on climatic conditions (Waltemeyer 1987). Annual variations in the timing and volume of streamflow in the Upper Rio Grande are strongly influenced by the El Niño-southern oscillation (ENSO) through its modulation of the seasonal cycles of temperature and precipitation and their effects on snow accumulation and melting (Lee et al. 2004). The ENSO cycles can be several years to decades long and can result in extended drought or wet periods. An extended period of below average precipitation occurred from the early 1940s through the mid 1970s and above average precipitation from 1981 through the mid 1990s (National Oceanic and Atmospheric Administration [NOAA] 2002). The analysis used to develop the representative 40-year synthetic flow sequence for input to the Upper Rio Grande Water Operations Model (URGWOM) shows similar periods in the Palmer Drought Severity Index (Appendix I).

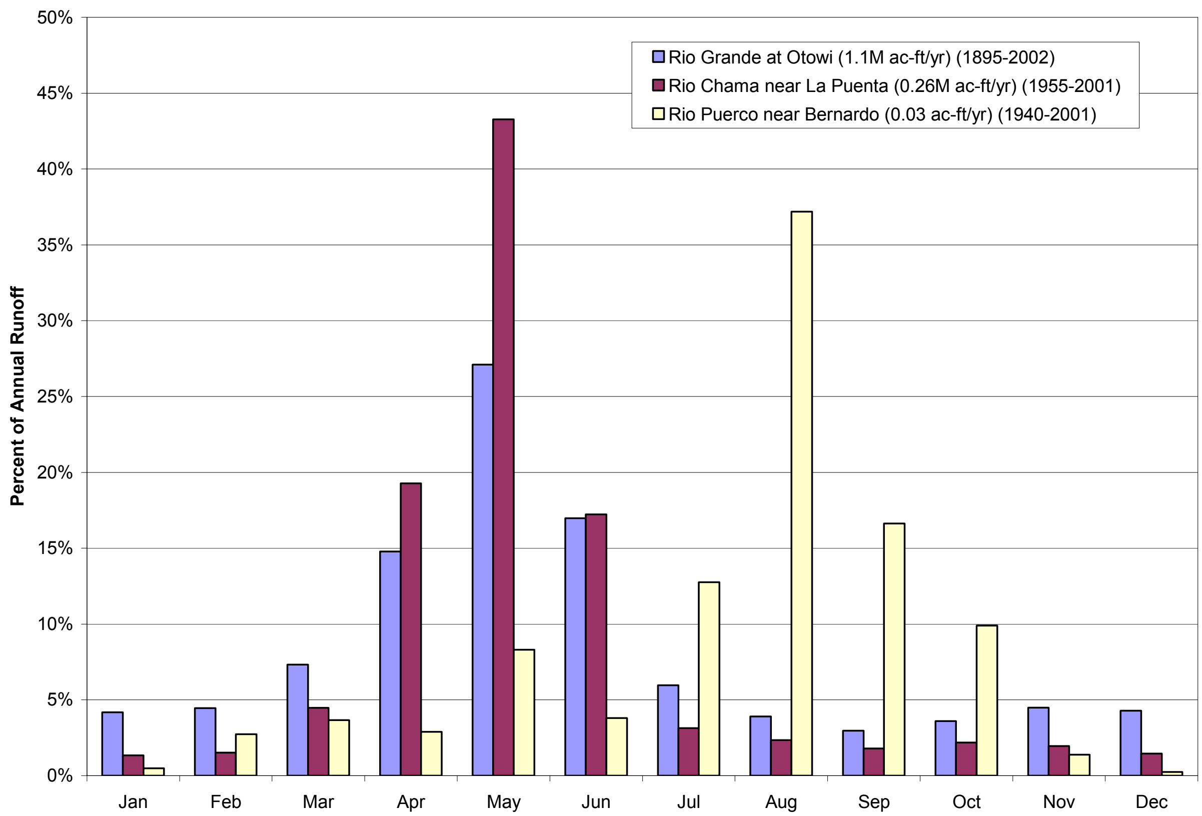
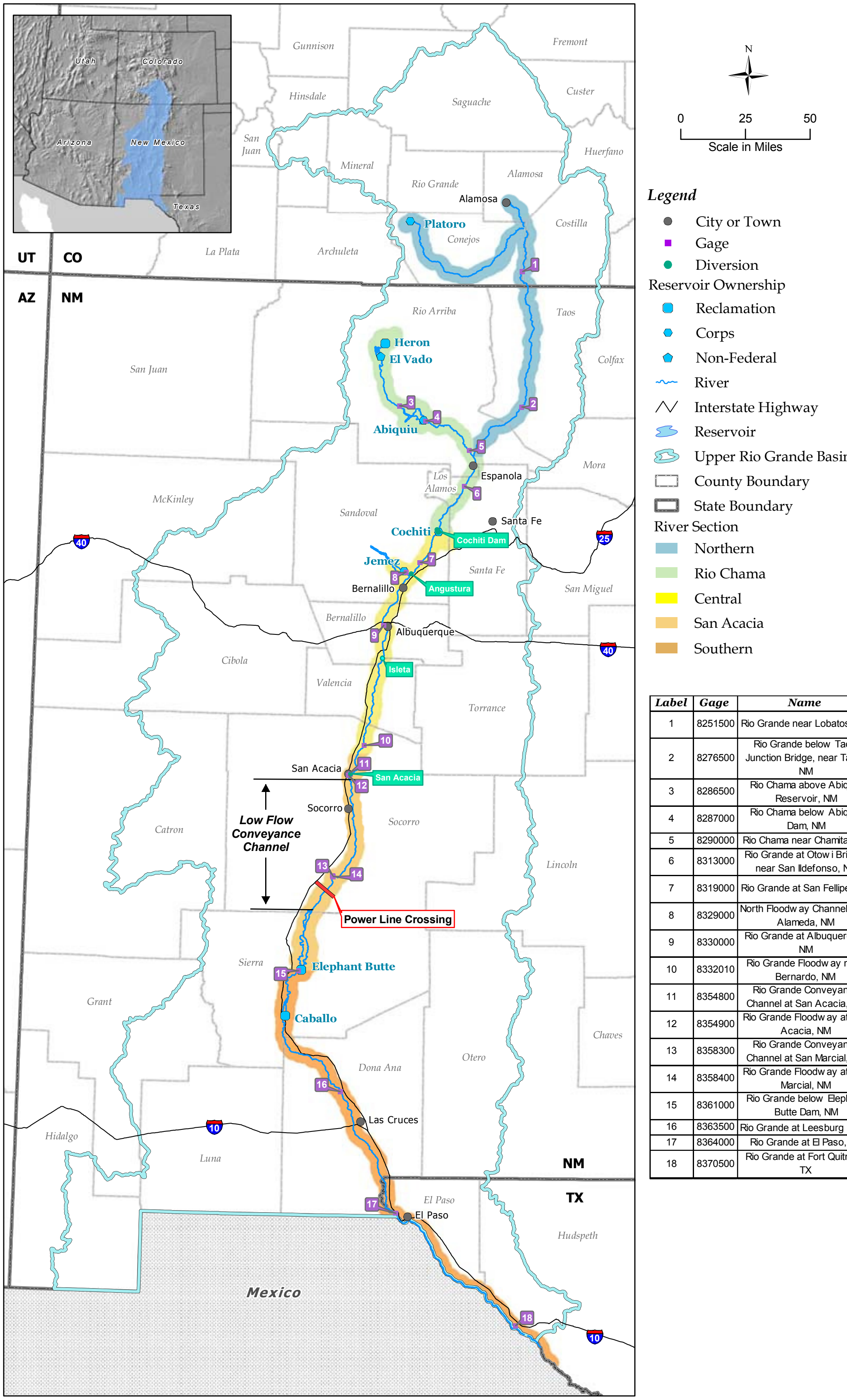


Figure 3-1. Average Monthly Distribution of Native Runoff of the Rio Grande at Otowi, Rio Chama Near La Puenta, and Rio Puerco Near Bernardo Gages (Over History Of Gage)

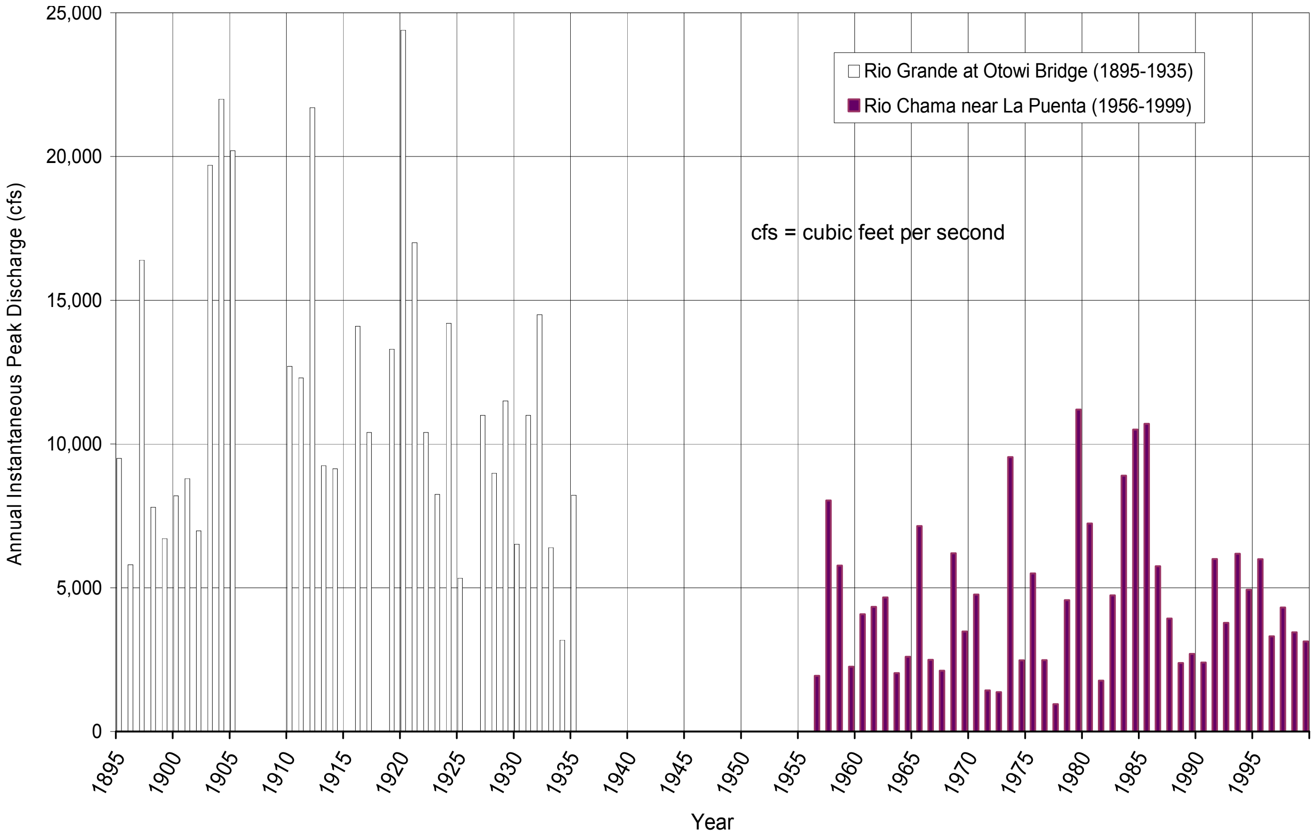
The annual flood regime varies significantly from year to year due to natural variability in climate and precipitation. During the period prior to completion of El Vado Dam in 1935, the approximate annual native flood peaks at the Otowi gage averaged about 11,600 cubic feet per second (cfs), but varied from about 24,400 cfs in 1920 to 3,200 cfs in 1934 (**Figure 3-2**). Annual native flood peaks at the Rio Chama near La Puenta gage averaged about 4,600 cfs during the period of record, but varied from about 960 cfs in 1977 to 11,200 cfs in 1979.

The lower elevation tributaries contribute a relatively small percentage of the annual runoff volume to the Rio Grande. Peak flows from the larger tributaries can equal or exceed the annual snowmelt peak flows in the mainstem, and typically carry high sediment loads that can have a significant effect on the behavior of the river (MEI 2002). For example, annual runoff at the Rio Puerco near Bernardo gage, where the flows are relatively unaffected by upstream augmentation or diversion, were less than 3 percent of the average native flow in the Rio Grande at Otowi during the same period. However, many of the floods in the Rio Puerco were of the same order of magnitude as those in the mainstem Rio Grande. Annual peak flows in the Rio Puerco averaged almost three times greater between 1940 and 1972 than they were during the subsequent four decades. Molnar and Ramirez (2001) attributed the decrease in annual peak flows to changes in precipitation patterns and channel conveyance characteristics in the Rio Puerco watershed, despite a statistically significant increase in annual precipitation over the past 50 years. The increase in precipitation occurred primarily during the autumn and spring, rather than the summer monsoon season. As a result, the average annual runoff did not change significantly because the decrease in monsoon-season runoff was balanced by an increase in long-term runoff.



Label	Gage	Name
1	8251500	Rio Grande near Lobatos, CO
2	8276500	Rio Grande below Taos Junction Bridge, near Taos, NM
3	8286500	Rio Chama above Abiquiu Reservoir, NM
4	8287000	Rio Chama below Abiquiu Dam, NM
5	8290000	Rio Chama near Chamita, NM
6	8313000	Rio Grande at Otowi Bridge, near San Ildefonso, NM
7	8319000	Rio Grande at San Fellipe, NM
8	8329000	North Floodway Channel near Alameda, NM
9	8330000	Rio Grande at Albuquerque, NM
10	8332010	Rio Grande Floodway near Bernardo, NM
11	8354800	Rio Grande Conveyance Channel at San Acacia, NM
12	8354900	Rio Grande Floodway at San Acacia, NM
13	8358300	Rio Grande Conveyance Channel at San Marcial, NM
14	8358400	Rio Grande Floodway at San Marcial, NM
15	8361000	Rio Grande below Elephant Butte Dam, NM
16	8363500	Rio Grande at Leesburg Dam
17	8364000	Rio Grande at El Paso, TX
18	8370500	Rio Grande at Fort Quitman, TX

1 **Map 3-1. Major Gages, Diversions, and Structures Along the Rio Grande**

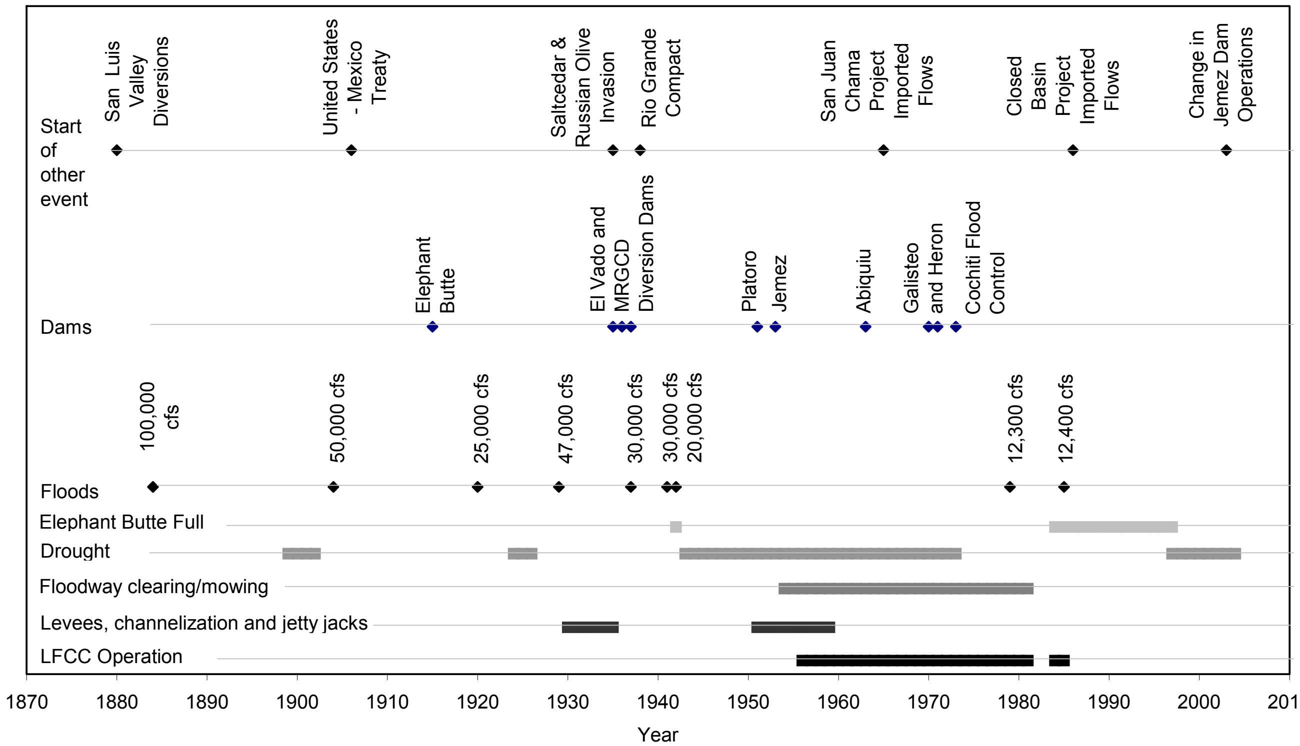


Note: Gaps within the period of record indicate that no gage data are available.

Figure 3-2. Recorded Annual Peak Flows During the Period Prior to Significant Flow Regulation (1895-1935) of the Rio Grande at Otowi Gage and at the Rio Chama Near La Puenta Gage

Human activities affecting flows in the Rio Grande system have been documented back to the arrival of Spanish settlers in the late 16th century (Wozniak 1997). Human activities are described in more detail in the Cultural Resources section of this chapter and in Appendix N. Significant changes in the Rio Grande occurred during the past century in response to a combination of human-induced factors (**Figure 3-3**). These alterations to the environment equate to significant changes in land use through time and space. Construction of reservoirs, changes to and expansion of historic irrigation conveyance systems, upland drainage networks, and bank stabilization have all served to modify the flow regime of the Rio Grande and associated groundwater recharge dynamics (Reclamation 1997; Scurlock 1998; Wozniak 1995). Many of these alterations have resulted in the general tendency for extending runoff hydrographs, reducing peak-flow runoff events, limiting dry-channel vegetative colonization (*i.e.,* new channel formation), and limiting lateral channel migration; resulting in a persistent and additive transition away from a more natural avulsive disturbance regime. These characteristics now dominate the nature and behavior of the Rio Grande.

Reservoirs along the Rio Chama and Rio Grande are operated by several agencies serving a variety of purposes, including flood control, sediment detention, and storage of native and imported water. Based on the available flow records, the average annual flow volume was higher during the past four decades than it was during the earlier periods due to a combination of higher than average precipitation during parts of the period and imported flows from the SJC Project.



Notes: cfs = cubic feet per second; LFCC = Low Flow Conveyance Channel; MRGCD = Middle Rio Grande Conservancy District

Figure 3-3. Timeline of Human Activities Since 1880 That Have Affected the Rio Grande

The eight major dams listed in Figure 3-3 affect flows in the river by storing and releasing water in a manner that generally decreases the flood peaks and alters the timing of the annual hydrograph, but they do not necessarily cause significant changes in the annual flow volume. The SJC Project, which imports flows into the basin, began operating in late 1971, thereby increasing flow in the system downstream from Heron Reservoir. The volume of imported San-Juan Chama water passing the Otowi gage has averaged about 54,000 acre-feet per year (AFY) since SJC Project inception (RGCC 2003).

The hydrologic characteristics of each reach have been characterized primarily based on flow records collected during the past century. These records provide a means of quantifying the most significant changes that occurred as a result of upstream flow regulation and storage, imported flows, cycles of drought and above average precipitation, and changes in land use. The following natural and human-caused hydrologic characteristics are particularly important to the existing geomorphology of each reach:

- Flows during the spring snowmelt season in April, May, and June typically make up more than half of the total annual runoff in the system. On an average annual basis, the total runoff volume was higher during the past four decades than it was in the earlier recorded period due to a combination of imported flows and higher than average precipitation during portions of that period.

- Flows associated with frequently occurring floods in the 1.5- to 10-year range are generally believed to have the most significant influence on channel form (Wolman and Gerson 1978). The morphologic characteristics of rivers in arid environments such as the Rio Grande are also strongly affected by larger, less frequent floods that create a disturbance regime that effectively "resets the clock" by altering the characteristics that develop during the intervening lower flow periods (Graf 1988). In spite of the increase in total runoff, both the average annual maximum mean daily flow (AAMMDF) (which is used to represent the mean annual flood peak) and the infrequent, large magnitude peak discharges have decreased in all reaches downstream from Cochiti Dam, presumably due to the presence of upstream dams.

The river and adjacent environs respond to cycles of drought and above average precipitation that occur over periods of several years through a variety of mechanisms, including increases in riparian vegetation, channel narrowing during drought periods, and channel widening through bank erosion and migration during wet periods. Generally, these processes vary widely over both time and space and represent a fundamental organizing force throughout the river system. Over the passage of time, different flow regimes (both high and low) have shaped the riparian plant community by means of deposition and scour; however, widespread and large-scale human alterations in the last century have muted this pattern and disrupted the natural disturbance regime (Crawford 1993; Reclamation 1997; Scurlock 1998; Wozniak 1995). The estimated native flows at Otowi gage over 60 years are shown on **Figure 3-4**. Channel widening is limited on the Rio Chama and Rio Grande by installed bank stabilization structures and by vegetation that becomes established within the channel margins (Reclamation 2004a).

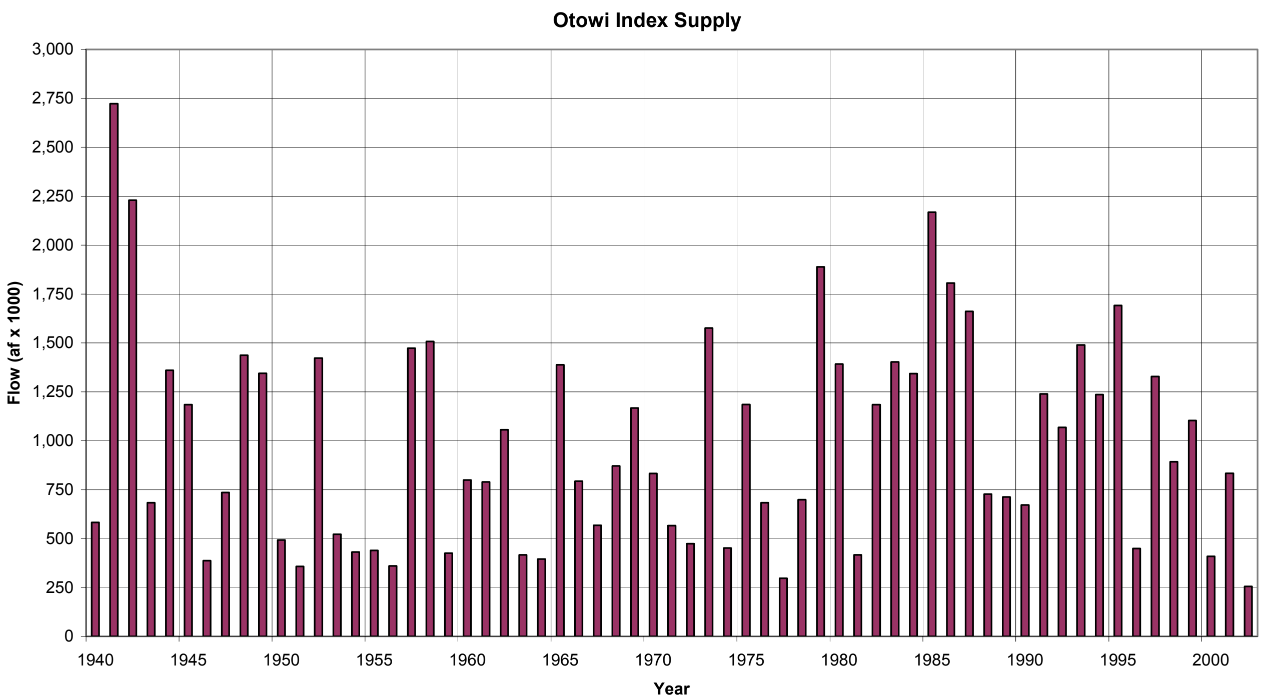


Figure 3-4. Historic Native Flows at Otowi Gage

To illustrate these flow changes, gages along the system were selected for comparison (**Figure 3-5)**. The two gages at San Acacia were combined into a single record to represent flows in the Rio Grande channel at that location before and after construction of the LFCC that began operation in late 1958.

Estimated native flows of the Rio Grande at Otowi Bridge and of the Rio Chama near Chamita gages both averaged about 20 percent higher during the period from 1972 to 2001 than during the earlier period of comparison between 1943 and 1971. This indicates that a significant part of the difference in flows throughout the system between the two periods is related to climatic conditions, in addition to the effects of the imported flows.

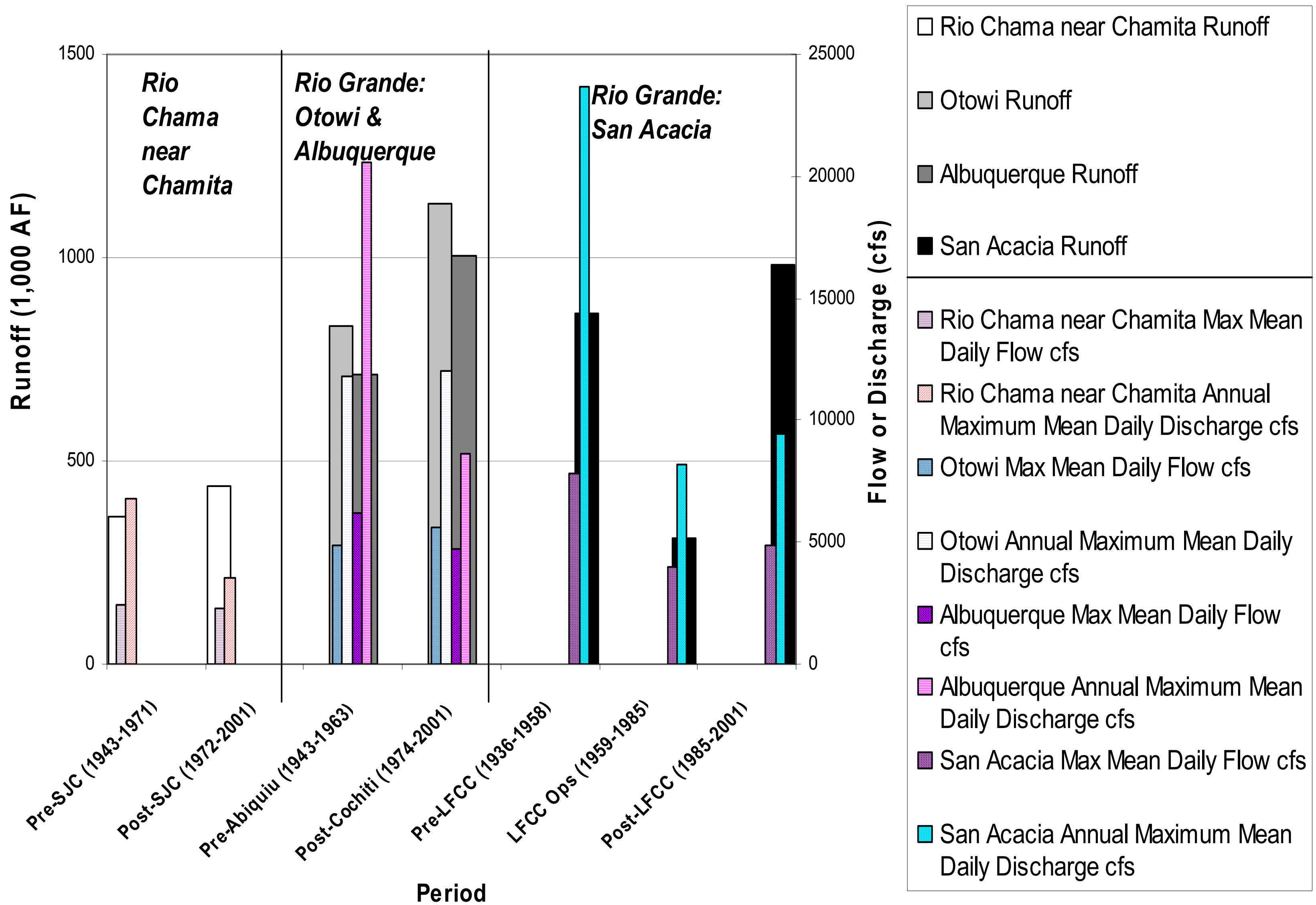


Figure 3-5. Runoff and Mean Daily Discharge from Selected Gages

Flows at the San Acacia gage have been primarily affected by operations of the LFCC that diverted an average of about 193,000 AFY between 1959 and 1985. In early 1985, diversions into the LFCC were discontinued, and essentially all of the upstream flows have passed into the downstream river channel since that time. Although the annual flow volume increased between the pre- and post-LFCC operations periods, the annual maximum flows decreased significantly in the portions of the sections downstream from Cochiti Dam. The decrease in annual maximum flow is believed to be related to operation of Cochiti Dam and other upstream dams.

Comparison of annual flood flows at San Acacia is confounded by operation of the LFCC between 1958 and 1984 and changes in Rio Puerco flows discussed previously. Compared to the 23-year period of record from 1936 to 1958 (prior to completion of the LFCC), the average annual maximum mean daily flow decreased during the period of LFCC operation (1959 through 1984). It then increased in 1985 after diversions to the LFCC were discontinued, though not to its original pre-LFCC levels. The maximum daily flow reflects this same trend.

The URGWOM Planning Model was developed to simulate the Rio Grande river system and its reservoirs. A 40-year planning horizon was chosen and a 40-year sequence of synthetic inflow hydrographs (see Figure 2-1) and initial reservoir storage volumes were developed to assist in evaluating the effects of the No Action Alternative and identified Action Alternatives. The pool of data available to support the modeling was restricted to the 25-year period from 1975 to 1999, which was wetter than the long-term average. A 40-year sequence of years was, therefore, derived from the available data using statistical sampling techniques, the Palmer Drought Severity Index, and the Otowi Index Supply to create a synthetic inflow hydrograph that would be representative of broader climatic conditions over the past 300 years (Appendix I). The resulting flow sequence has 5 average flow years followed by sequential blocks with flows representative of 7 drought years, 15 average years, 8 wet years, and 5 average years. The average annual flow volume at the Otowi gage for the 40-year synthetic sequence is about 934,000 acre-feet (AF), which is about 18 percent less than the average Otowi Index Supply between 1975 and 1999 of about 1.15 million AF.

In summary, the flood regime has decreased as a result of upstream control and regulation. The net effect of the hydrologic changes is a less dynamic river because the energy that drives channel change is primarily associated with the flood regime.

3.2.2 Geomorphology

The geomorphic characteristics of rivers represent the integration of physical factors present within the basin and drainage network. The existing reach-specific characteristics of the Rio Grande and Rio Chama vary significantly due to a range of natural and human-caused factors whose effects have varied temporally and spatially. These factors can be broadly grouped into three categories:

- Hydrology, which encompasses precipitation and the range, duration, and magnitude of flows (as provided in Section 3.2.1);
- Sediment supply and transport, which encompasses the characteristics of the upstream and tributary sediment supply, and the bed-material characteristics along the reach, and directly affects the vertical and lateral stability of the river including the planform; and
- Local controls that include bedrock outcrop, older terraces, and other erosion-resistant material, as well as structures and channelization.

Each of these three categories includes a natural component governing the overall characteristics of any reach and a human component that has altered those natural characteristics to varying degrees. In a general sense, the channel size and planform characteristics have developed in response to the magnitude and duration of the flows and the sediment supply to each reach over the long term, including the period prior to significant human influence. These general characteristics of each specific reach are modified by local factors, including geology, tributary sediment supply, and local climate, particularly as it affects riparian vegetation, which results in significant variability about the general trend, even in the absence of human activity. Although there is evidence of human activity that could have affected the morphology of the river dating back at least several centuries, the current morphology of the rivers is more strongly influenced by human activities that have occurred in the past century, including changes affecting hydrology and sediment supply, construction of river training and flood protection works, and installation of irrigation diversion structures (Williams and Wolman 1984; Graf 1994). Geomorphic characteristics of reaches in the Rio Chama, Central, and San Acacia Sections are summarized in **Table 3-1**.

Table 3-1. Summary of Geomorphic Characteristics of the Rio Grande Reaches

River Section	Reach	Description	Reach Length (miles)	Typical Median (D_{50}) Bed Material Size (mm)[1,2,3]	Average Gradient (ft/mi)[1,2,3]	Active Channel Width (feet)[1,2,3]	Approximate Post-Cochiti Dam 2-year Flood Peak (cfs)[3]
Rio Chama	7	Abiquiu Dam to confluence with Rio Grande	32	30–75	14	75-120	1,800
	8	Rio Grande/Rio Chama Confluence to Otowi Gage	14	20–50	9	370	6,160
	9	Otowi Gage to Cochiti Dam	—	—	—	—	6,160
Central	10	Cochiti Dam to Bernalillo (NM 44 Bridge)	27	10–20	5	320	4,640
	11	Jemez Canyon Dam to Rio Grande Confluence	—	—	31	—	664
	12	Bernalillo to Isleta Diversion Dam	34	<1–3	5	420	5,610
	13	Isleta Diversion Dam to Rio Puerco confluence	42	<1–2	4	510	5,710
San Acacia	14	Rio Puerco confluence to Elephant Butte Reservoir	66	<1	4	455	4,590

Notes: [1] Corps 1996a,b
[2] Reclamation 2001
[3] Appendix H
cfs = cubic feet per second
ft/mi = feet per mile
mm = millimeters

The current channel morphology is also affected by changes in distribution of annual precipitation over periods of a few to several years. Streamflow trends (Waltemeyer 1987) parallel the long-term precipitation/drought trends discussed in Section 3.2.1. The rivers responded to these trends through a range of adjustments. Changes in channel width of the Rio Grande parallel these trends (Massong et al.

2002; Reclamation 2004), but causality is confounded by the extensive channelization and flow regulation that occurred during the same time period.

3.2.3 Sediment Supply and Transport

Historically, the Central and San Acacia Sections had one of the highest sediment loads of any river in the world, with measured sediment concentrations as high as 200,000 parts per million (ppm) (Baird 1998). The suspended sediment concentrations in the San Acacia and San Marcial floodways include sediment delivered by the Rio Salado and Rio Puerco. During the past half-century, sediment concentrations have fallen significantly, primarily as a result of reduced sediment supply due to upstream dam construction. Analyses of the available data (MEI 2002) show significant decreases in suspended sediment concentrations throughout the Rio Grande (**Figure 3-6**).

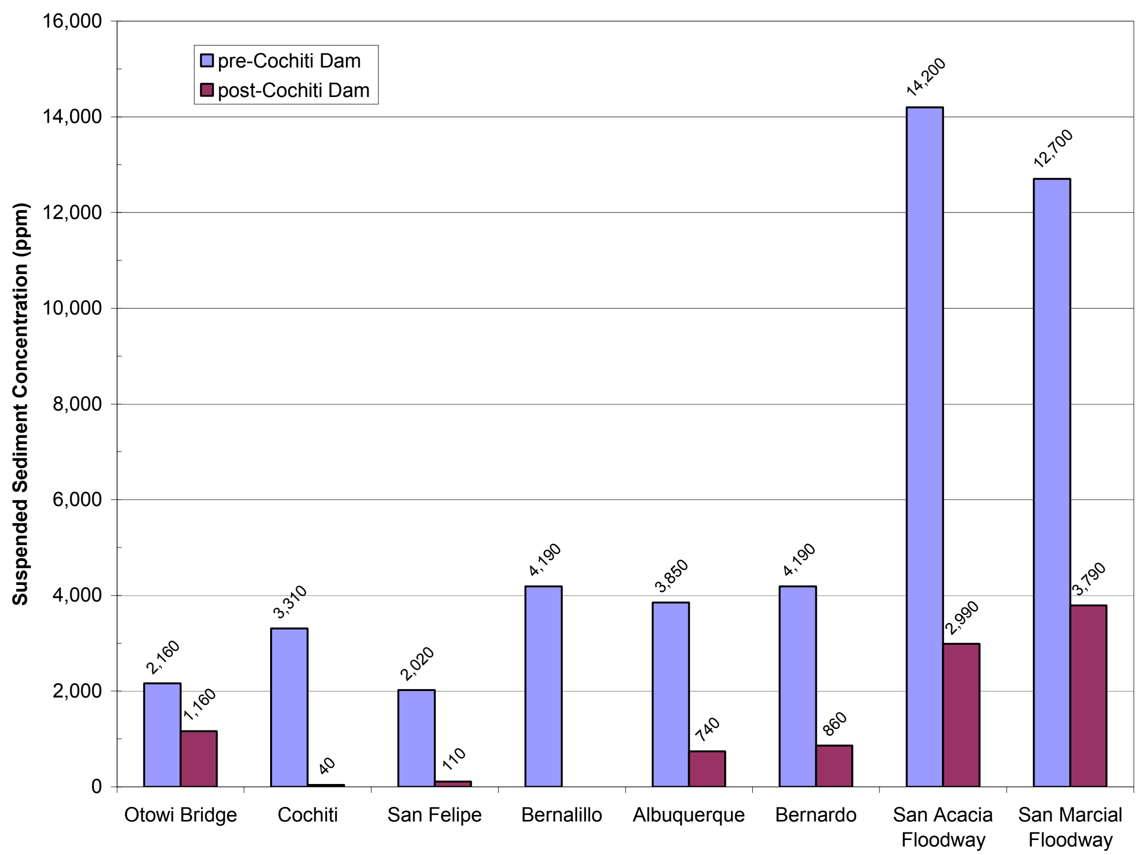


Figure 3-6. Average Annual Suspended Sediment Concentrations in the Middle of the Project Area during the Pre- and Post-Cochiti Dam Period (Appendix H)

Although the dams have undoubtedly affected downstream sediment loads, other factors are also involved, including changes in land use that decrease overland erosion rates; increases riparian vegetation and bank stabilization that decrease lateral erosion; and a general decrease in erosive energy associated with reductions in the magnitude of flood flows. Existing bed-material characteristics are the result of the combined effects of local geology, base flows, tributary sediment supply, hydrologic impacts of reservoir operations, dam-related reductions in downstream sediment supply, channel morphology, and hydraulics.

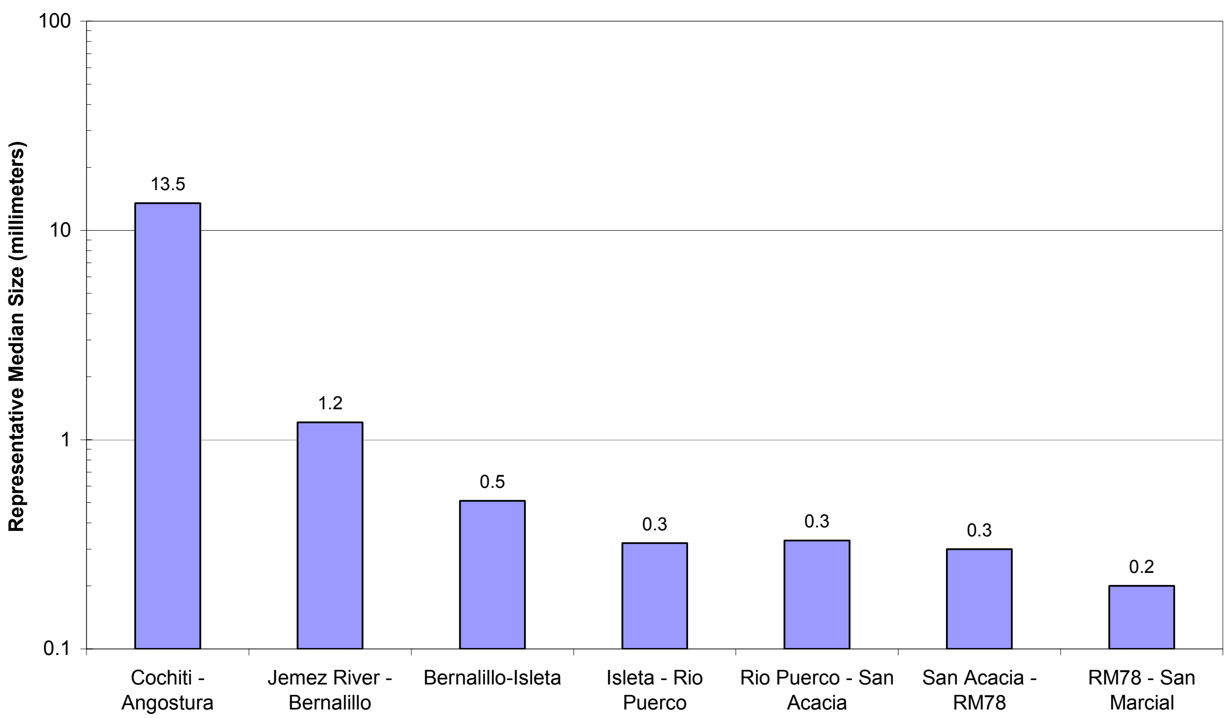
Rio Chama Section

The Rio Chama downstream from Abiquiu Dam (Reach 7) is primarily a single-thread, gravel-bed channel, in which the dominant bed-material grain size is 30–75-millimeters (mm) with increasing amounts of sand in the downstream direction (Corps 1996b). The sediment supply at the upstream end of this reach was effectively eliminated by Abiquiu Dam, which has probably caused the coarsening of the bed material compared to pre-Abiquiu Dam conditions. The portion of the sediment supply derived from bank erosion has also likely decreased over time due to the presence of significant bank protection along this reach. Bank protection slows formation of in-channel habitat.

The bed of the Rio Grande between the confluence with the Rio Chama and the head of Cochiti Reservoir (Reaches 8 and 9) is also composed predominantly of gravel with median grain sizes of 20–50-mm range. Based on suspended sediment data collected at the Otowi gage, the sediment supply to this reach also appears to have decreased over time (Appendix H).

Central Section

The bed material between Cochiti Dam and Elephant Butte Reservoir (along reaches 10, 12–14) generally becomes increasingly fine-textured in the downstream direction (**Figure 3-7**). However, between Cochiti Reservoir and Bernalillo (Reach 10), there has been a significant coarsening trend since the completion of Cochiti Dam in 1973 (Lagasse 1994; MEI 2002). Both the coarsening and degradation trends in this reach are typical of the expected response downstream of Cochiti Dam. Downstream from Bernalillo, bed material in the Rio Grande transitions to primarily sand, with typical median grain sizes decreasing from coarse sand between Bernalillo and Isleta Diversion Dam (Reach 12) to medium sand between Isleta and the confluence with the Rio Puerco (Reaches 12 and 13) (MEI 2002).



Based on post-1990 data collected between May 1 and August 31.
Source: MEI 2002

Figure 3-7. Representative Median (D50) Surface Bed-Material Size for Reaches of the Rio Grande Downstream from Cochiti Dam

San Acacia Section

Downstream from the Rio Puerco, the predominant bed-material size is in the fine to medium sand range; however, substantial gravel is also present locally, particularly near the mouth of the Rio Salado and at confluences with the numerous eastside tributaries. The bed material has also coarsened somewhat since the early 1970s in the reach downstream from the San Acacia Diversion Dam, although the median bed-material size remains in the medium sand range throughout most of the reach. Bed-material sizes in other portions of the reach between Isleta Diversion Dam and the head of Elephant Butte Reservoir, as represented by data collected at Bernardo and San Marcial, has remained relatively constant during the post-Cochiti Dam period. Integration of bed-material transport relationships over the post-Cochiti dam average annual hydrograph shows that annual bed material load increases in a downstream direction.

3.2.4 Local Controls and the Integrated Effects on Morphology

A variety of natural and constructed controls affect the morphology and dynamics of the Rio Chama and Rio Grande in the project area. These controls include:

- The bedrock canyon that limits lateral movement in the most upstream portion of the Rio Chama below Abiquiu Dam (Reach 7) and in the Whiterock Canyon section of the Rio Grande (Reach 9);
- Relatively coarse-grained tributary fans that control the river location, width, and gradient at several locations along the Rio Chama and Rio Grande, such as those at Rio Ojo Caliente on the Rio Chama and Arroyo Tonque on the Rio Grande;
- The Belen-Socorro uplift that affects the profile of the Rio Grande in Reaches 13 and 14;
- The presence of erosion-resistant terraces and local bedrock outcrops that limit lateral migration, such as at the Coronado State Monument upstream of Bernalillo (Map 3-1);
- The presence of dams that affect the hydrology and sediment supply for downstream reaches;
- The cycles of drought and above-average precipitation that occur over periods of several years;
- The presence of irrigation diversion structures that provide local base level controls, interrupt the sediment flux in the river, and divert flows from the river; and
- Riverside drains intercept hundreds of cfs as groundwater between the river and drain system.

The Central and San Acacia Sections of the Rio Grande have been affected by human intervention since at least the 1800s, when water used for irrigation in Colorado's San Luis Basin reduced the natural flows in the river by 40 to 60 percent (Natural Resources Commission 1938). By 1880, approximately 125,000 acres of land were under cultivation in the valley of the Central and San Acacia Sections, which led to increased water diversion from the river and removal of riparian vegetation (Crawford et al. 1993). Widespread drought, often punctuated by devastating floods, waterlogging, salinization, alkali poisoning of arable lands, and the breakup of many community-based land grants, caused the total area of irrigated lands to sharply decline in these sections to about 45,000 acres by the mid-1920s (Wozniak 1995). The decrease in irrigated lands resulted in a proportional reduction in the amount of water removed from the river for irrigation.

The earliest detailed information available on the geomorphic characteristics of the river was the 1917–1918 survey. However, by the time this survey was conducted, the hydrology and sedimentology of the reach had changed considerably (Berry and Lewis 1997; Scurlock 1998), and there is uncertainty as to whether the form of the river at that time was in equilibrium.

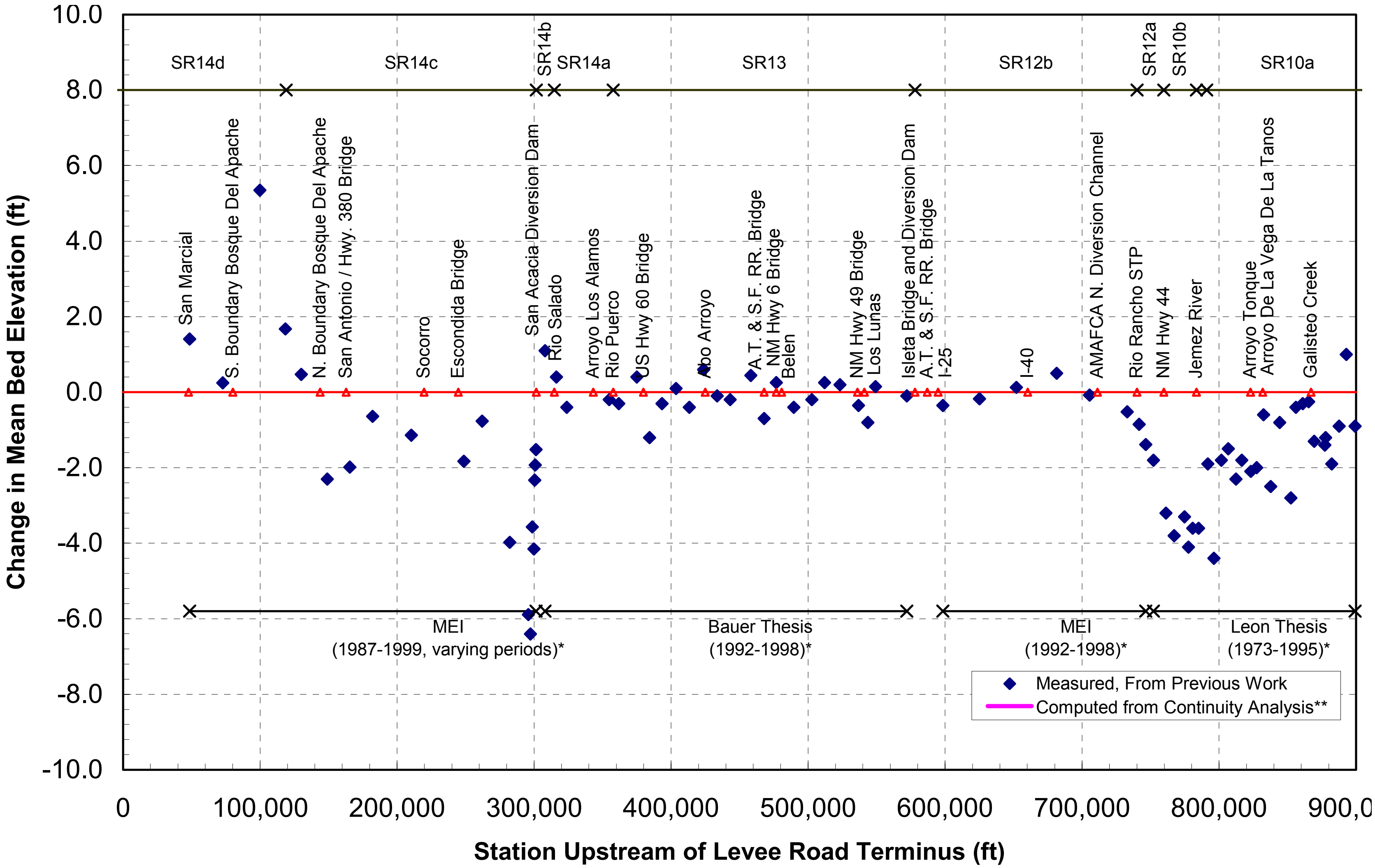
Channel width data developed from the 1917–1918 survey shows a general trend of increasing channel width in the downstream direction to near the southern boundary of the Bosque del Apache National Wildlife Refuge (NWR). A much narrower channel was observed downstream of Bosque del Apache

NWR (MEI 2002; Reclamation 2004a). Extensive channelization of the river occurred during the early and middle parts of the 20th century, and by the early 1960s, a considerable portion of the river had been narrowed and stabilized with jack fields (see Appendix G for authorizations). Although some reaches are continuing to narrow as a result of reductions in peak flows due to drought, upstream flow regulation, channel degradation, and increased amounts of riparian vegetation, average changes in channel width after 1972 are much smaller than the changes observed between 1918 and 1972 (MEI 2002; Reclamation 2004a).

During the recent drought period, a significant amount of vegetation has established on low-elevation bars and floodplain surfaces, further decreasing channel widths and width variability. During previous drought periods, this vegetation has typically been mechanically removed to improve flood conveyance along the reach (Berry and Lewis 1997). The response of the river to future high flows, including the potential for removal of recently established riparian vegetation by the river, is not known.

Since at least the mid-1970s, the Rio Grande has downcut by varying amounts throughout most of the reach between Cochiti Dam (subreach 10a) and the Bosque del Apache NWR (**Figure 3-8**), which is the approximate beginning of deposition that continues downstream to the head of Elephant Butte Reservoir (approximately the lower end of subreach 14d). Refer to Appendix H, Sediment Continuity Analysis, for the background data. Surveyed cross-sections for the period 1992–1998 indicate that the degradation trend has slowed or stopped in the portions of the reach from about Bernalillo downstream to at least San Acacia (subreaches 12a to 14c). The water surface at the Albuquerque gage located at the Central Avenue Bridge lowered by about 2.5 feet between the late 1970s and the late 1980s in response to the low to intermediate ranges of flows.

In response to the combined effects of both natural and human factors, the Rio Chama below Abiquiu Dam and the Rio Grande downstream of Cochiti Dam are less dynamic rivers than they had been historically. The present channel widths are considerably less than they had been historically and, where channel downcutting has occurred, the channels are deeper. Immediately below the dams, bed materials have coarsened. However, bed materials along most of the reaches are composed of sands, with reaches of gravel that affect channel morphology. Changes in hydrology and channel morphology have reduced the frequency of overbank flows in most of the reaches, except where aggradation is occurring downstream of the Bosque del Apache NWR.



Notes: SR = subreach; *Most Recent Period of Data used to Compute Elevation Change; **Using average annual change in bed elevation multiplied by number of years used in measured data.

Figure 3-8. Computed Annual Aggradation/Degradation Volumes for Each Subreach under Existing Conditions (without bed-material Supply from the Jemez River)

3.3 Existing Biological Conditions

3.3.1 Aquatic Habitats

Dams and diversions have altered flow regimes in most river reaches and have reduced sediment load to the river channel. Collectively, these efforts have resulted in a river that is considerably different from how it had been historically (Dudley and Platania 1997). Although these anthropogenic alterations have resulted in improved flood control and modification of river flows for the benefit of humans, the effects on the aquatic system have not been positive. Alterations to aquatic habitat have resulted in changes in species composition and numbers of fish from those historically found in the river (Appendix L). A description of these structures and their effects, as well as other information on the aquatic system, are included in Appendix L.

The major dams and irrigation diversions are physical barriers to natural channel flow in the Rio Grande, barriers that limit movement of fish and drifting insects. Habitat fragmentation in riverine systems is of concern because some fishes rely on river connectivity for survival and reproduction. Areas of poor water quality may further fragment a river, if these areas become unsuitable for fish or invertebrates.

Habitat availability is the main factor in the success or decline of a species (Carlson and Muth 1989). Other driving factors include population genetics, genetic variability, food availability, and predation or competition by native or non-native species. Important habitat elements for survival and reproduction typically include temperature, substrate type, seasonal flow variations, and adequate water quality.

In rivers, the aquatic food base is composed of various algae, aquatic plants, and aquatic invertebrates. Physical features like water velocity, substrate, temperature, and sediment inputs affect these food sources. Impoundments and diversions affect the structure of the aquatic food base (Thorp and Covich 1991).

In reservoirs, the aquatic food base consists of small plants and animals known as phyto- and zooplankton. These important ecosystem components may be affected by water temperature, water quality, and water residence time within a reservoir (Wetzel 1975).

3.3.1.1 Riverine Habitat and Fish Community

Each reach and its fish community are described in the following sections. The Rio Grande silvery minnow (RGSM) is the only endangered riverine fish within the project area and is addressed in more detail in Section 3.3.3—Threatened, Endangered, and Special Status Species. Appendix L (Biological Resources) lists the reaches and identifies fish species known to occur, including life history information. **Table 3-2** summarizes riverine fish distribution throughout the project area.

Northern Section

Fish species in the Rio Conejos include brown, brook, rainbow, and Rio Grande cutthroat trout. The Conejos River is managed as a put-and-take fishery and stocked with hatchery fish in late spring. Brown and rainbow trout are stocked by the New Mexico Department of Game and Fish (NMDGF) at several places on the Rio Grande west of Taos from the John Dunn Bridge south to the Taos Junction Bridge off State Road 96. Naturally reproducing cutbows (rainbow trout and cutthroat trout hybrids) occupy the Rio Grande Gorge, as do northern pike (MWH 2001). Native and non-native fish species occurring in the Northern Section are summarized in Table 3-2 (MWH 2001).

Rio Chama Section

The fish community of the Rio Chama, the largest tributary of the Rio Grande, may be contrasted from pre- and post-impoundment periods. Prior to the construction of Abiquiu Dam in 1963, the fish community consisted primarily of native main stem minnows including the RGSM, Rio Grande bluntnose shiner, Rio Grande chub, and Rio Grande sucker which reached the northern limit of their ranges in the Rio Chama near Abiquiu (Bestgen and Platania 1990). Since construction of Abiquiu Dam, the community has shifted towards more headwater type fauna (Platania 1996). Introduced brown trout are self-sustaining in the system, and rainbow trout occur but are generally not self-sustaining. Some fishes stocked into Abiquiu Reservoir occasionally escape into the lower reaches of the Rio Chama. Some native minnows, which persisted following dam construction, are generally considered headwater species adapted to cool waters with relatively high velocities. Native and non-native fish species occurring in the Rio Chama Section are summarized in Table 3-2.

Aquatic habitat in the Rio Chama was temporarily altered by short-term construction at Abiquiu Dam affecting sediment load and water quality during the late 1980s and into the 1990s (Corps 2001b). River habitat downstream of Abiquiu Dam represents an altered ecosystem, which includes alteration of the natural hydrologic pattern in terms of flow and temperature, and reduction of suspended sediment. These changes have modified the distribution and abundance of aquatic habitats available to native fish (Dudley and Platania 2001).

Central Section

In a study conducted by Reclamation (PEC 2001), 26 fish species, representing nine families, were collected along the Central Section from 1995 to 1999. Native and non-native fish species occurring in the Central Section are summarized in Table 3-2.

The lower Rio Jemez reach extends from Jemez Canyon Dam to the confluence of the Jemez River with the Rio Grande. The most common species in this reach were common carp, red shiner, fathead minnow, white sucker, and western mosquito fish (Hoagstrom 2000). The study found the RGSM was the tenth most abundant species in the lower Rio Jemez, representing 1.2 percent of all fish collected. The flathead chub has also been found in the Rio Jemez below Jemez Canyon Dam (Dudley and Platania 2000).

Table 3-2. Riverine Fish Distribution in Project Area

Common Name	SECTION					
	Northern	Rio Chama	Central	San Acacia	LFCC	Southern
Native Minnows						
Red shiner	—	Present	Present	Present	Present	Present
Rio Grande chub	—	Present	Present	—	Present	—
Rio Grande silvery minnow	—	—	Present	Present	—	—
Golden shiner	—	—	—	—	—	Present
Fathead minnow	—	Present	Present	Present	Present	Present
Bullhead minnow	—	—	—	—	—	Present
Flathead chub	—	Present	Present	Present	Present	—
Longnose dace	—	Present	Present	Present	Present	Present
Other Native Species						
Gizzard shad	—	—	Present	Present	Present	Present
Threadfin shad	—	—	—	—	—	Present
Mosquitofish	—	Present	Present	Present	Present	Present
Smallmouth buffalo	—	—	Present	Present	—	Present
Bluegill	—	—	Present	Present	Present	Present
River carpsucker	—	Present	Present	Present	Present	Present
Rio Grande sucker	—	Present	—	—	—	—
Flathead catfish	—	—	Present	Present	—	Present
Longnose gar	—	—	—	—	—	Present
Rio Grande Cutthroat trout	Present	—	—	—	—	—
Non-native Species						
Longfin dace	—	—	—	—	—	Present
Black bullhead	—	Present	Present	Present	Present	Present
Yellow bullhead	—	—	Present	Present	Present	Present
Fantail goldfish	—	—	—	—	—	Present
White sucker	—	Present	Present	Present	Present	—
Common carp	—	Present	Present	Present	Present	Present
Northern pike	Present	—	—	—	—	—
Plains killifish	—	—	—	—	—	Present
Channel catfish	—	Present	Present	Present	Present	Present

Common Name	SECTION					
	Northern	Rio Chama	Central	San Acacia	LFCC	Southern
Green sunfish	—	Present	Present	Present	Present	Present
Longear sunfish	—	—	Present	Present	Present	Present
Rainwater killifish	—	—	—	—	—	Present
Smallmouth bass	—	Present	—	Present	—	Present
Spotted bass	—	—	—	—	—	Present
Largemouth bass	—	Present	Present	Present	Present	Present
White bass	—	—	Present	Present	—	Present
Striped bass	—	—	—	Present	—	—
Rainbow trout	Stocked	Stocked	Stocked	Present	Present	Present
Yellow perch	—	Present	Present	Present	Present	Present
Sailfin molly	—	—	—	—	—	Present
White crappie	—	—	Present	Present	—	Present
Black crappie	—	Present	Present	—	—	Present
Brown trout	Stocked	Stocked	Present	—	—	Present
Brook trout	Present	—	—	—	—	—
Grey redhorse	—	—	—	—	—	Present
Walleye	—	—	—	Present	—	Present

Notes:
Stocked = Species is stocked to maintain population size; Present = Self-sustaining population.
— means not present.
LFCC = Low Flow Conveyance Channel
Data summaries from references cited under each section in text.

San Acacia Section

The San Acacia Section contains two parallel channels—the mainstem channel and the LFCC. This section of the Rio Grande contains the greatest abundance of RGSM remaining in the wild. Native and non-native fish species occurring in the San Acacia Section are summarized in Table 3-2.

The mainstem channel is 300 to 600 feet wide and generally less than 3 feet deep. It is a braided, meandering river with a sand substrate that carries a high silt load and has an average velocity of less than 3 feet per second. No major tributaries enter the Rio Grande between the San Acacia diversion dam and the Elephant Butte delta (Dudley and Platania 2000). Habitat characteristics include runs, flats, shorelines, and islands. Debris piles provide low velocity habitat for many fish species including the RGSM. Riverine habitat in this stretch is considered to be more representative of natural conditions than habitats elsewhere in the project area, despite the parallel channel configuration in this section. Numerous factors influence the composition of fish species, including stream channelization, altered river discharge patterns, instream barriers to fish movement, competition from non-native species, water quality degradation, and channel drying (Reclamation 2000a).

The LFCC was constructed to reduce depletion losses for water destined for storage in Elephant Butte Reservoir by diverting water from the Rio Grande into a narrower, deeper, more hydraulically efficient channel (Reclamation 2000a). The LFCC runs parallel to the western side of the Rio Grande from the San

Acacia Diversion Dam to the delta of Elephant Butte Reservoir and is capable of maintaining a flow of 2,000 cfs. When operational water is diverted to the LFCC at San Acacia, but the downstream portion of the LFCC is currently nonfunctional due to high flow destruction in 1988 and sedimentation. The LFCC acts as the principal drain, capturing groundwater seepage and return flow from the Middle Rio Grande Conservancy District (MRGCD) (Reclamation 2000a). Average drainage flow through the LFCC has been between 200 to 300 cfs near San Marcial (Reclamation 2000a).

Southern Section

Six native fish species occur from Elephant Butte Dam to Caballo Reservoir, including gizzard shad, red shiner, river carp sucker, mosquito fish, fathead minnow, and smallmouth buffalo; 22 non-native or uncertain status fish species also occur in this section (Propst et al. 1987).

From Caballo Dam to El Paso, 22 species of fish have been recorded, eight of which are native to the system (USFWS 2001). Native and non-native fish species occurring in the Southern Section are summarized in Table 3-2.

3.3.1.2 Reservoir Habitat and Fish Community

Each reservoir and its fish community are described in the following sections. Appendix L lists the reservoirs and identifies known fish species, including life history information. **Table 3-3** summarizes reservoir fish distribution throughout the project area.

Platoro Reservoir

The Colorado Division of Wildlife stocks Platoro Reservoir with kokanee salmon, brown trout, and rainbow trout. White suckers are also present in relatively high abundance (Alves 2002).

Heron Reservoir

Heron Reservoir supports a cold-water fishery managed by NMDGF. Sport fish species include rainbow trout, lake trout, and Kokanee salmon. The FWS stocks 400,000 rainbow trout in the reservoir in April and another 200,000 trout in August of each year and does not expect natural reproduction to sustain the rainbow trout population. The NMDGF stocks Kokanee salmon in the reservoir, with approximately 475,000 fish stocked each year in January (Ortiz 2001).

El Vado Reservoir

El Vado Reservoir supports a cold-water fishery with several warm-water species. NMDGF annually stocks 220,000 rainbow trout, 100,000 Kokanee salmon in April and 100,000 rainbow trout in October. Rainbow trout in El Vado Reservoir constitute a put-grow-and-take fishery; natural reproduction is not expected to sustain populations (Ortiz 2001).

Table 3-3. Distribution of Fish Species in Reservoirs of the Project Area

Common Name	Platoro	Heron	El Vado	Abiquiu	Cochiti	Elephant Butte	Caballo
Black bullhead	—	—	—	—	Present	Present	—
Black crappie	—	—	—	—	Present	Present	Present
Blue catfish	—	—	—	—	—	Present	—
Bluegill	—	—	Present	Present	Present	—	—
Brown trout	Stocked*	Present	Present	Present	Present	Present	—
Bullhead minnow	—	—	—	—	—	Present	—
Channel catfish	—	Present	Present	Present	Present	Present	Present
Common carp	—	Present	Present	Present	Present	—	—
Rio Grande cutthroat trout	—	Present	Present	Present	—	—	—
Fathead minnow	—	Present	Present	Present	Present	Present	—
Flathead catfish	—	—	—	—	—	Present	—
Flathead chub	—	—	—	Present	Present	—	—
Gizzard shad	—	—	—	—	Present	Present	—
Goldfish	—	Present	Present	Present	Present	Present	—
Green sunfish	—	Present	Present	Present	Present	Present	—
Kokanee salmon	Stocked*	Stocked*	Stocked*	Present	—	—	—
Lake trout	Present	Present	Present	Present	—	—	—
Largemouth bass	—	—	—	Present	Present	Present	Present
Mosquitofish	—	Present	Present	Present	—	Present	—
Northern pike	—	—	—	—	Present	Present	—
Rainbow trout	Stocked*	Stocked*	Stocked*	Stocked*	Present	Present	—
Red shiner	—	Present	Present	Present	Present	Present	—
Rio Grande chub	—	Present	Present	Present	Present	—	—
Smallmouth bass	—	—	—	Present	Present	Present	—
Smallmouth buffalo	—	—	—	—	—	Present	—
Striped bass	—	—	—	—	Present	Stocked*	Present
Threadfin shad	—	—	—	—	Present	Present	—
Walleye	—	—	—	Stocked*	Stocked*	Present	Present
White bass	—	—	—	—	Present	Present	Present
White crappie	—	Present	Present	Present	Present	Present	Present
White sucker	Present	Present	Present	Present	Present	—	—
Yellow perch	—	Present	Present	Present	—	Present	—

Notes:
No sustainable reproduction*
Stocked = Species is stocked to maintain population size; Present = self-sustaining population.
— means not present.
Data summaries from references cited under each section in text.

Abiquiu Reservoir

Abiquiu Reservoir supports a cold-water fishery and a warm-water fishery. Most fish populations other than rainbow trout and walleye in the reservoir are sustained by natural reproduction. Rainbow trout are stocked by the NMDGF in April, October, and November, with 100,000, 290,000, and 100,000 fish stocked, respectively. Approximately 200,000 Kokanee salmon are stocked in April. Walleye are occasionally stocked by the NMDGF in April with approximately 1,000,000 fish (Ortiz 2001).

Cochiti Reservoir

Cochiti Reservoir is primarily a warm-water fishery with a limited cold-water fishery. Cold-water fish species include rainbow trout and brown trout. Approximately one million walleye are stocked in April by the NMDGF (Ortiz 2001).

Jemez Canyon Reservoir

Jemez Canyon Reservoir is operated as a dry reservoir specifically for flood control purposes; there is no permanent water in the reservoir and therefore it does not support a sustained fishery. Prior to the change in operations, the species known to occur included largemouth bass, white bass, channel catfish, common carp, green sunfish, white crappie, white sucker, gizzard shad, and small numbers of brown and rainbow trout (Corps 2000).

Elephant Butte Reservoir

Elephant Butte Reservoir is primarily a warm-water fishery with a limited cold-water fishery. NMDGF stocks 300,000 striped bass in the reservoir in early June or July, and the FWS stocks 10,000 fish in June of each year (Ortiz 2001).

Caballo Reservoir

Fish species include striped bass, white bass, white crappie, largemouth bass, walleye, and channel catfish.

3.3.2 Riparian and Wetland Habitats

Riparian areas include the soils, vegetation, and associated wildlife that border waterways, including open sand bars along the main channel. Riparian vegetation comprises much of the upper Rio Grande basin riparian zone and exhibits a diversity of plants and structural types. Forest composition is varied and may include both native tree species and non-native species in different combinations.

3.3.2.1 Upper Rio Grande Basin Riparian Vegetation Communities

Hydrologic Factors Affecting Riparian Ecosystems

Water operations at the various facilities on the Rio Grande affect the surface and groundwater available to the riparian ecosystem. Periodic overbank flooding is necessary to the health of established native plant communities and literally "…creates the distribution of different communities and age classes" (Scurlock 1998). Regulated flood flows may prevent the overbank floods necessary to scour away existing vegetation and make new seedbeds for cottonwoods and other native trees (Scurlock 1998). Riparian areas that seldom receive overbank flooding show a definite lack of both structural and species diversity. Canopy trees tend to be mature, same-aged stands that are not regenerating. The understory becomes littered with deadfall, a fuel load that inhibits growth of desirable grasses, forbs, and other understory species (**Figure 3-9a**). Restricted flow regimes changed the nature of riparian areas in the Rio Grande, adversely affecting cottonwood and other native plants. Many areas of the Rio Grande floodplain, both inside and outside the levees, contain relic stands of mature cottonwood and willow that have not flooded for several decades. Riparian vegetation that is not regularly flooded is more vulnerable to encroachment by non-native saltcedar and is extremely vulnerable to fire because of the accumulation of debris that occurs with reduced peak flow events (Ellis et al. 1996). The timing, duration, and magnitude of peak flows are critical to habitat creation and maintenance. Peak flow variability contributes to the diversity of vegetation and wildlife. Seasonally flooded riparian zones exhibit both structural and species diversity in the canopy and understory. Banks are scoured and reshaped, forming depressions that support vital wetland areas and associated species (**Figure 3-9b**).

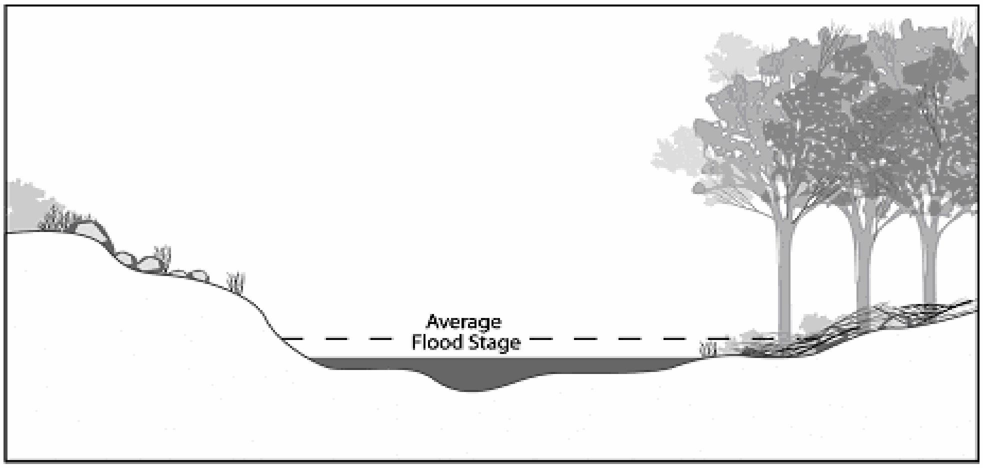


Figure 3-9a. Vegetation Response to No Overbank Flooding

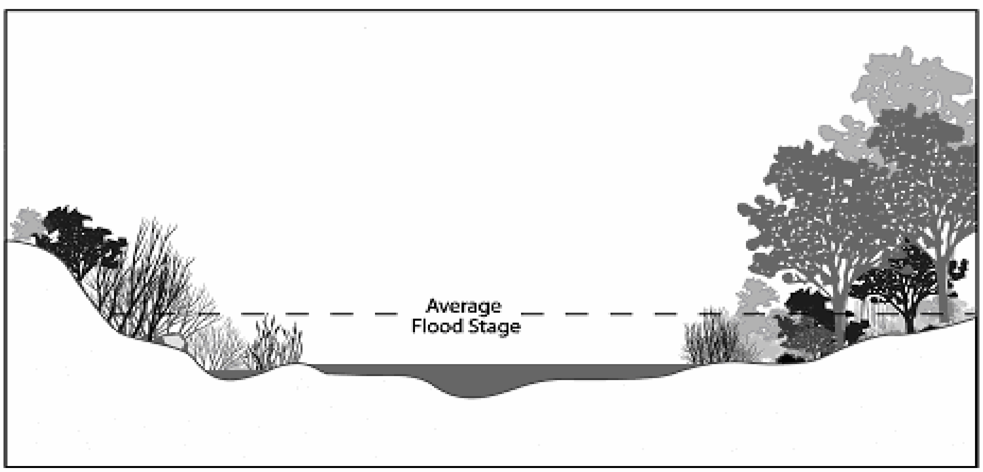


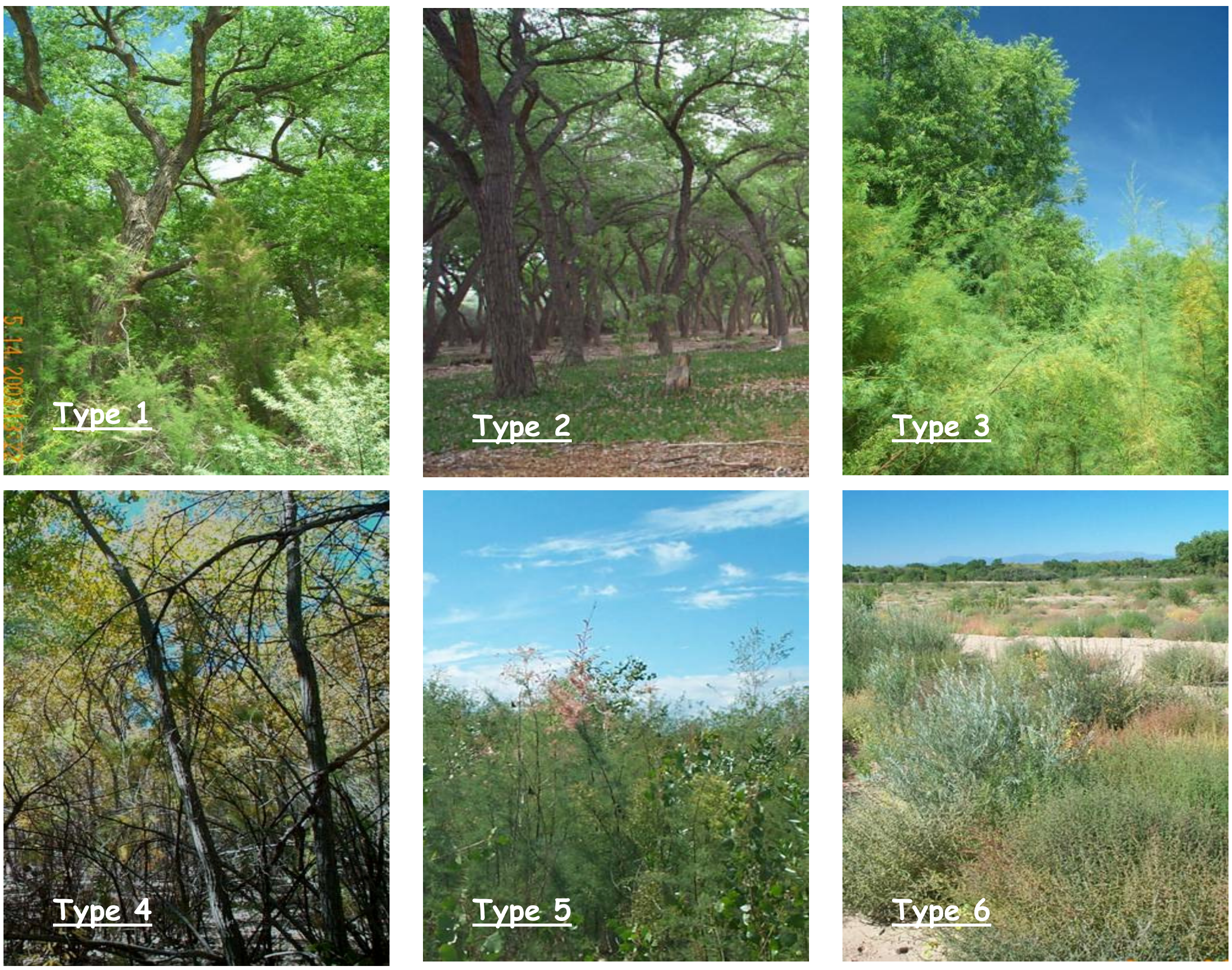
Figure 3-9b. Vegetation Response to Seasonal Overbank Flooding

Figure 3-9. Vegetation Response to Overbank Flooding in Riparian Zone

Riparian Vegetation Types

Cottonwood riparian forests provide the greatest structural and species diversity along the Rio Grande. The most common forests—called the "bosque"—include forests dominated by cottonwood or Goodding's willow. A bosque contains a variety of understory species such as willow, seepwillow, and New Mexico olive, with some non-native species such as Russian olive and saltcedar. One of the most prevalent species in certain reaches, saltcedar can exclude all other woody vegetation. Although saltcedar stands provide some habitat for wildlife, they inhibit valuable native vegetation and thus are less valuable than a mixed native forest. Open sand bars typically have sparse growths of young cottonwood, coyote willow, and saltcedar as well as perennial grasses, sedges, and forbs.

Riparian vegetation of the Rio Grande was studied using six structural classes of riparian wetland vegetation described by Hink and Ohmart (1984). This classification scheme is described in the Bosque Management Plan (Crawford et al. 1993) and a modified approach is used in this EIS (**Figure 3-10**). Beginning with the lowest biomass category, Type 6 is very young vegetation that may be short (5 feet or under) or sparse. Type 5 classification occurs when plant heights reach 5 to 15 feet, creating young stands with dense shrubby vegetation. The remaining four structural classes constitute further variations in height and density of both canopy and understory species. Type 4 is represented by intermediate-aged trees (20–40 feet), with little or no shrubby vegetation in the understory. Type 3 is represented by intermediate-aged trees with dense, shrubby understory vegetation. Type 2 is represented by mature and mid-aged trees (over 40 feet) with little or no shrubby vegetation in the understory. Type 1 is represented by mature and mid-aged trees with a dense understory of shrubby, mixed-height vegetation.



Type 1: Mature and mid-aged trees with shrubby vegetation at all heights.
Type 2: Mature and mid-aged trees with little or no shrubby vegetation.
Type 3: Intermediate-aged trees with dense, shrubby vegetation.
Type 4: Intermediate-aged trees with little or no shrubby vegetation.
Type 5: Young stands with dense, shrubby vegetation.
Type 6: Very young, low, and/or sparse vegetation.

Figure 3-10. Characteristics of Riparian Forest Vegetation Based on Hink and Ohmart 1984 Classification System

A vegetation survey was undertaken between 2002 and 2004, jointly funded by the ESA Collaborative Program, NMISC, and the Corps. The survey used field studies and interpretation of color infrared aerial photography taken in August 2002 to map riparian vegetation between Abiquiu Dam and Elephant Butte Reservoir. Over 50,000 acres were mapped using these methods, of which 30,665 acres were assigned to one of the vegetation categories. The detailed results of the vegetation mapping are included in Appendix L.

To evaluate habitat value, this EIS correlates the mapped Hink and Ohmart vegetation types with the "Resource Types" categorized by the FWS. The FWS developed Resource Community Type designations to assist in making consistent and effective recommendations for the protection and conservation of valuable fish and wildlife resources. Additional detail on the relationship between Hink and Ohmart structural types and FWS Resource Category types can be found in Appendix L, Biological Resources Technical Report.

- *FWS Resource Category Type 1:* Habitat is of high value for evaluation of species and is unique and irreplaceable on a national basis or in the ecoregion. Within the Rio Grande project area, this type represents marshes and other high-value wetlands.
- *FWS Resource Category Type 2:* Habitat is of high quality for evaluation species and is relatively scarce or becoming scarce on a national basis or in the ecoregion. On the Rio Grande, Type 2 is found in riparian vegetation dominated by native species in the overstory or understory or both, and most wetlands all fall within this category.
- *FWS Resource Category Type 3:* Habitat is of high to medium value for evaluation species. On the Rio Grande, Type 3 is found in riparian vegetation dominated by mixtures of native and non-native species. The mitigation goal is, "no net loss of habitat value while minimizing loss of in-kind habitat value." Riparian vegetation dominated by mixtures of native and non-native species is considered to be FWS Type 3 vegetation.
- *FWS Resource Category Type 4:* Habitat is of medium to low value for evaluation species. Within the Rio Grande project area, Type 4 is exhibited by monotypic exotic vegetation, sparsely vegetated areas, and disturbed or bare land.

Hydrology strongly influences species composition in riparian systems. Changes in surface water hydrology may affect both structure and composition of riparian communities.

Marshes and emergent wetlands require the greatest hydrologic support, primarily from groundwater. Most marshes are indirectly dependent on surface flows in the river and nearby unlined drains and channels to keep groundwater levels at or near the ground surface elevation all year (Cowardin et al. 1979; Corps 1987a).

Willow-dominated communities require frequent surface saturation and shallow groundwater. These include low stature (H&O Type 5) coyote willow communities, intermediate height (H&O Type 3) communities with coyote willow or Gooding's willow in the understory, or mature (H&O Type 1) tree willow communities. These communities thrive on lengthy periods of saturation, 5- to 10-foot depth to groundwater, and low frequency and duration of droughts (Crawford et al. 1993; Stromberg and Patten 1991; Stromberg, Patten, and Richter 1991).

Cottonwood-dominated communities require spring overbank flooding every few years for natural seedling establishment and early success (Crawford et al. 1993). Cottonwood forests are tolerant of inundation during the growing season. Unlike willows, however, they do not survive year-round saturation (Kozlowski 2002). Once established, cottonwoods can maintain themselves through maturity in areas with infrequent surface inundation if they have reliable groundwater at 6 to 16 feet depth (Crawford et al. 1993; Graf and Andrew 1993; Stromberg and Patten 1991a). Most of the existing mature cottonwood gallery forests in the Central Section, both Hink and Ohmart Types 1 and 2, have not received overbank flooding in decades and are not regenerating as a result (Crawford et al. 1993).

Saltcedar generally reaches heights of 20 to 40 feet and does not form an overstory in structural Hink and Ohmart Types 1 or 2, although it may be present in the understory. Riparian forests dominated by saltcedar tend to be of Hink and Ohmart Types 3, 4 or 5, depending on age, and may become monotypic stands as shade and accumulating debris and salt prevent other species from establishing in the understory. Dense stands of saltcedar usually have deeper water tables (15 to 30 feet below the surface) than will support native cottonwoods (Horton 1977). Saltcedar communities are able to tolerate infrequent overbank flooding and longer periods of drought, as a result. Greater detail on riparian vegetation communities and hydrologic factors affecting them can be found in Appendix L.

Riparian Vegetation Communities in the Rio Grande Floodplain

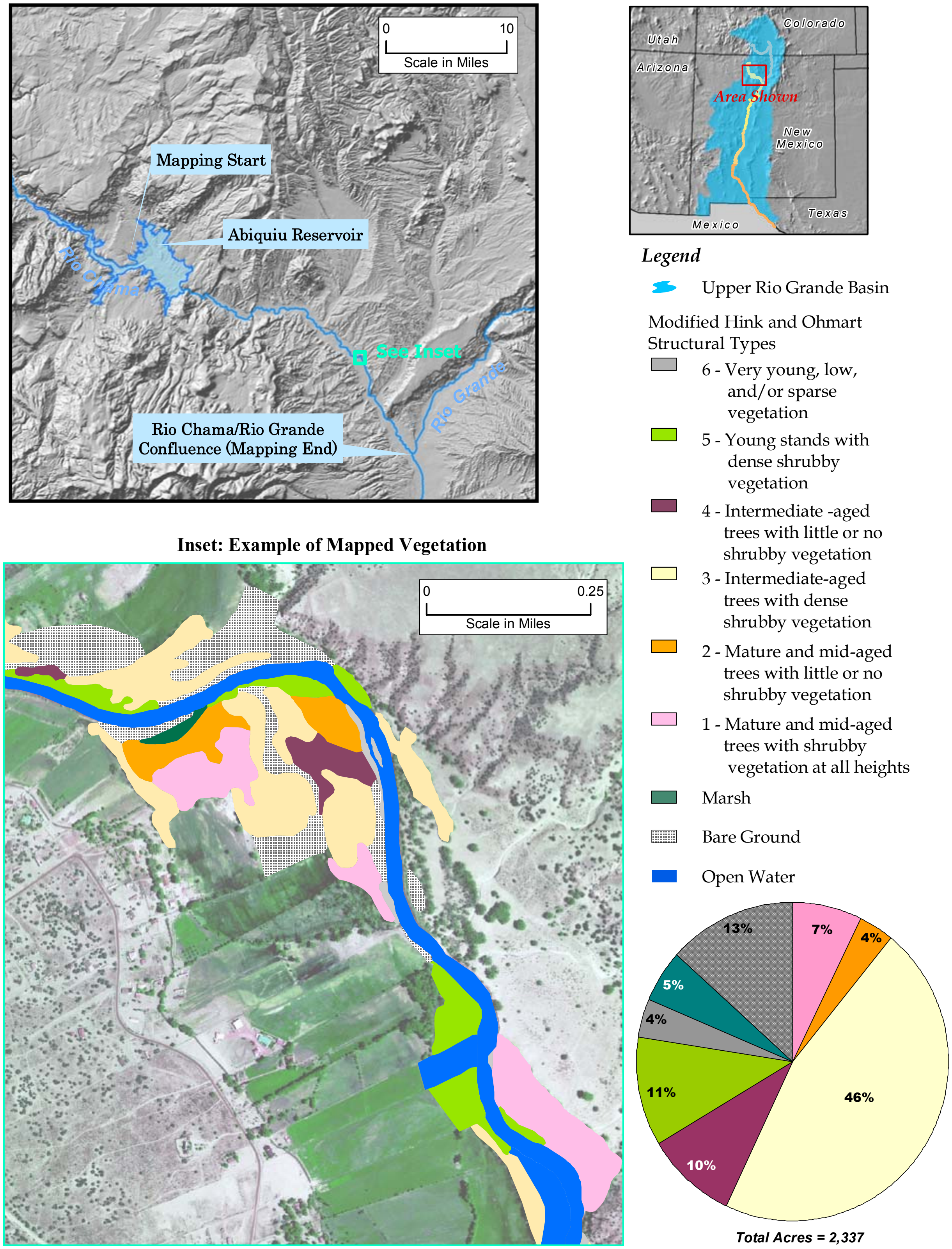
Northern Section

From the south boundary of Alamosa NWR in southern Colorado downstream to La Sauses, Colorado, the floodplain supports scattered stands of willow, narrowleaf cottonwood, and oxbow wetlands. In the Rio Grande gorge in northern New Mexico, riparian vegetation is limited to isolated stands that are restricted by the steep cliffs and deeply incised, narrow floodplain. Downstream of the gorge, the floodplain opens and species such as saltcedar, coyote willow, and box elder, with a few small isolated stands of cottonwood, are present in New Mexico. Cottonwoods become more common near Embudo and cottonwood bosque is well developed near Velarde. The Northern Section is not influenced by operations at any of the facilities under consideration for change in this EIS. Therefore, detailed vegetation mapping was not conducted for the Northern Section.

Rio Chama Section

The Rio Chama Section is characterized by a steep gradient and steep canyon walls, with a narrow floodplain in most areas. The riparian areas between Abiquiu Dam and the confluence of the Rio Chama and Rio Grande were mapped in 2002–2003 (Appendix L). The unmapped upper portion of the Rio Chama, from Heron Reservoir to the delta of Abiquiu Reservoir, has a narrow riparian zone with patchy stands of willow and saltcedar. The occasional intermediate-to-mature cottonwood canopy has an understory of Russian olive and New Mexico olive.

Areas upstream of the pool of Abiquiu Reservoir are considered unlikely to be affected by changes in water operations. Only the portions of the Rio Chama Section downstream from Abiquiu Dam were mapped to classify vegetation, primarily through photo-interpretation. The majority (2,337 acres) of the vegetation mapped in this section (3,073 acres) is within Reach 7 that extends from Abiquiu Dam to the confluence with the Rio Grande. Approximately 14 percent of the mapped riparian vegetation is composed of mature and mid-aged cottonwood forest, while over half of the mapped vegetation consists of intermediate and young stands of native trees with dense shrubby understory vegetation (Hink and Ohmart Types 3, 4, and 5). These riparian forest areas are interspersed with about 20 percent openings vegetated with grasses, forbs, and 13 percent composed of brushy vegetation between 5 and 15 feet tall. Native species comprise almost 22 percent of the riparian vegetation of the Rio Chama Section, with areas dominated by non-native species like Russian olive and saltcedar accounting for about 60 percent. Representative riparian vegetation mapped in this section is summarized on **Map 3-2.**



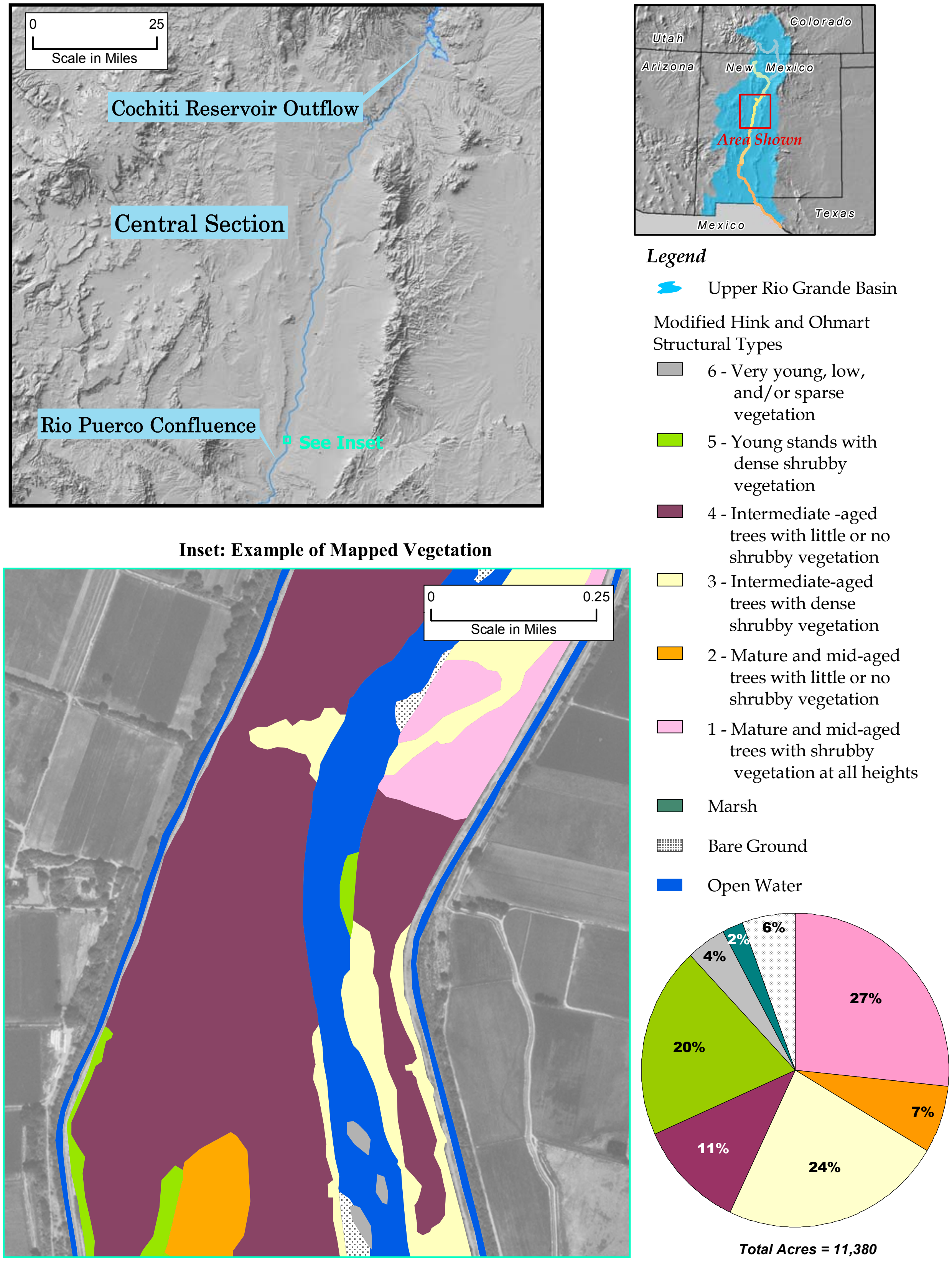
Map 3-2. A Sampling of Current Riparian Vegetation in Reach 7 of the Rio Chama Section

Central Section

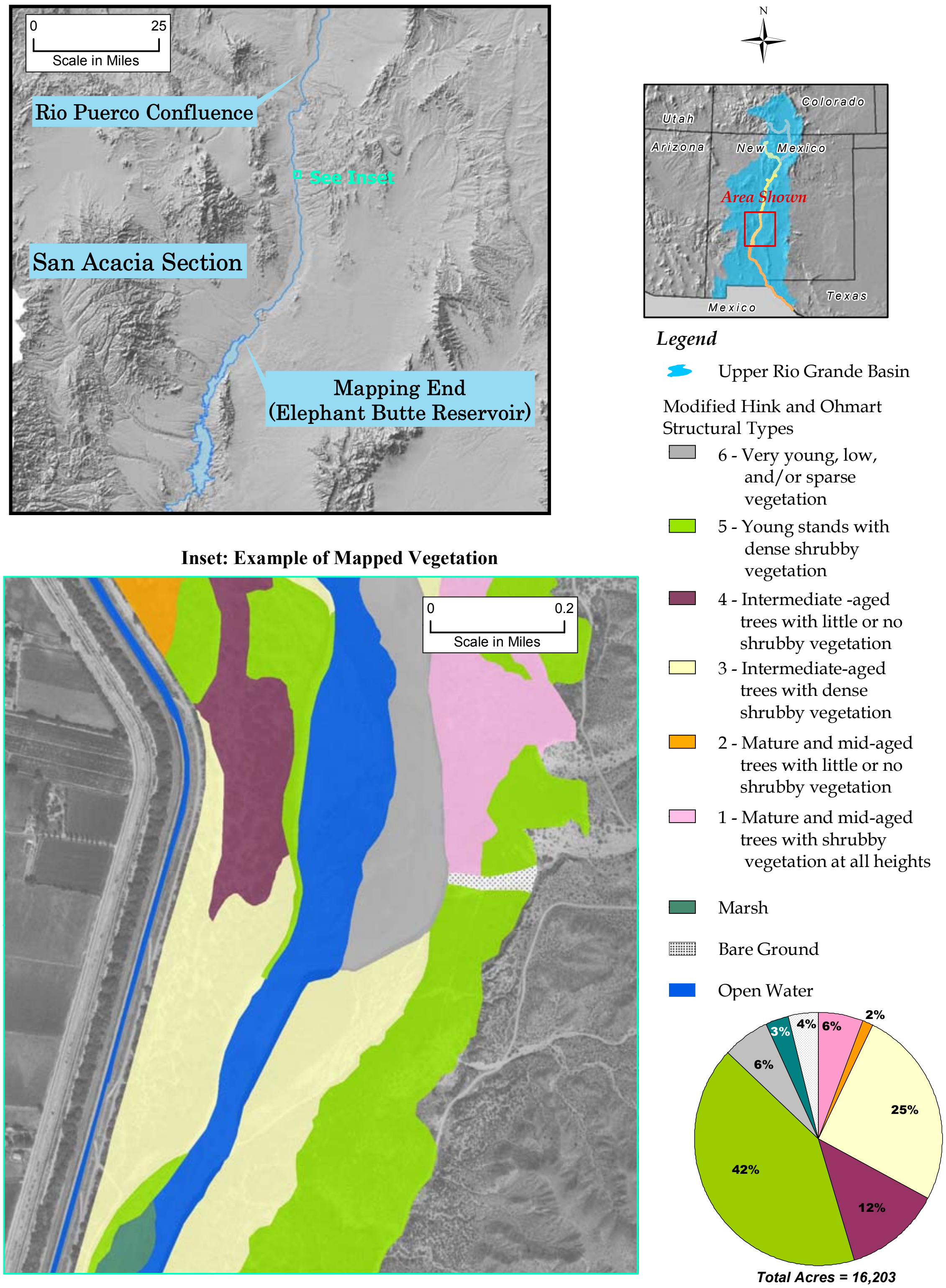
The Central Section contains the largest vegetative component of mature riparian forest in the study area. Of the 11,380 acres of vegetation mapped in the Central Section, 34 percent is composed of mature cottonwood gallery forest with a high canopy. Most of the bosque in the Central Section has a dense shrubby understory, although almost 7 percent of the riparian area is composed of cottonwood gallery forest with little or no understory vegetation. An additional 35 percent of the total vegetation consists of intermediate-sized riparian forests, often with dense understory and very high biomass. Young stands of trees, with or without shrubby undergrowth, make up 20 percent of the mapped vegetation, and approximately 10 percent consists of bare ground or sparse vegetative cover. An estimated 66 percent of the Central Section mapped vegetation is dominated by non-native species, primarily Russian olive, Siberian elm, and saltcedar, with approximately 28 percent native species, some with small amounts of invasive plants included but not dominant. Representative riparian vegetation mapped in this section is shown on **Map 3-3.**

San Acacia Section

The San Acacia Section contains 16,203 acres of riparian vegetation mapped within the levees, the largest area of riparian vegetation mapped in the project area. Only 7 percent of the riparian vegetation in the section is composed of mature or mid-aged cottonwood gallery forest, mostly in the area downstream from San Marcial. Over 80 percent of the riparian vegetation is composed of intermediate and young stands of woody vegetation, most with dense shrubby undergrowth categorized as Hink and Ohmart Types 3 and 5. The San Acacia Section contains the highest proportion of non-native vegetation in the three sections mapped. Approximately 80 percent is dominated by saltcedar and other non-native species, which have limited value as riparian habitat. Other communities are highly valuable as habitats, such as the 460 acres of marsh within the section. Representative riparian vegetation mapped in this section is summarized on **Map 3-4.**



Map 3-3. A Sampling of Current Riparian Vegetation in the Central Section



Map 3-4. A Sampling of Current Riparian Vegetation in the San Acacia Section

Southern Section

The Southern Section was not included in the 2002–2003 vegetation survey because potential operational changes are not likely to affect areas south of Elephant Butte Reservoir. Below Elephant Butte Reservoir, the channel is confined and flows are regulated, resulting in decreased vegetation density and diversity. Occasional patches of saltcedar and willow occur where seasonal tributaries enter the floodplain. Shoreline vegetation along Caballo Reservoir is primarily saltcedar shrubland with mesquite in some areas. The floodplain below Caballo Reservoir includes some riparian forest, riparian grassland, and riverbank shrub-scrub, but primarily saltcedar shrubland (Reclamation 2004). Vegetation surrounding the American Dam is park-like with a few scattered cottonwoods and native grasses. The river corridor below American Dam is predominantly grassland except for a narrow band of saltcedar shrubland along the river shore (USIBWC 2004).

Vegetation Changes in the Central Section

The 1982 Hink and Ohmart vegetation surveys covered most of the Central Section, specifically from Bernalillo Bridge on Highway 550 to the Jarales Bridge, approximately 8 miles south of Belen (Hink and Ohmart 1984). That vegetation survey and mapping occurred seven years after initial operations at Cochiti Reservoir. The 2002-2003 survey conducted for the Water Operations Review and EIS covered the same geographic area and used similar methods. Data gathered by the two surveys allow a comparison of vegetation composition classes and structural types to identify changes over two decades.

The information, discussed in detail in Appendix L, is summarized by the changes in cover types shown in **Figure 3-11**.

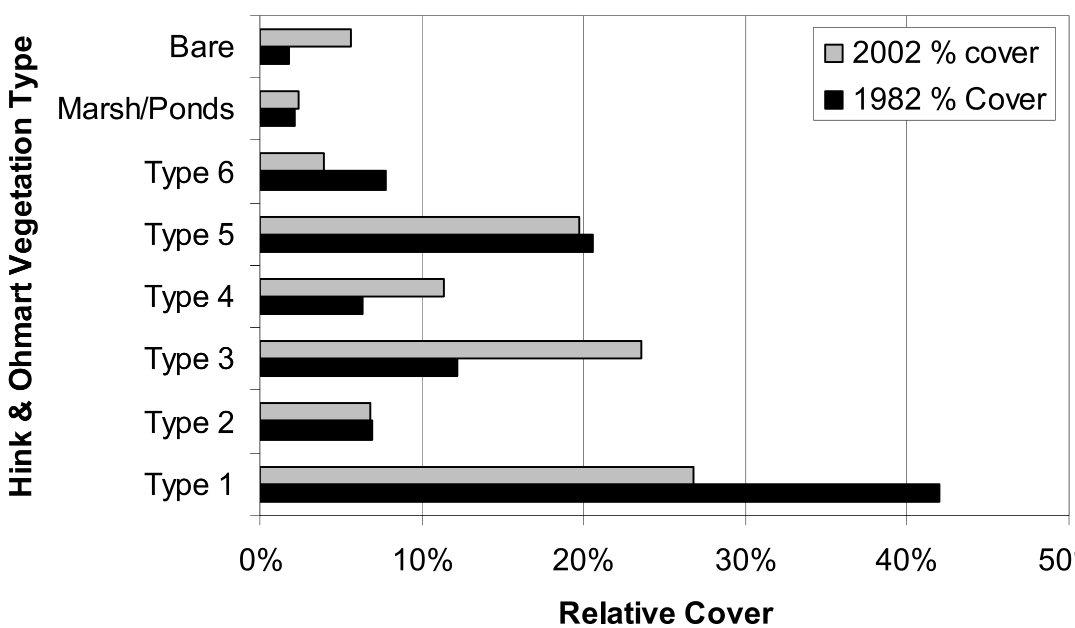


Figure 3-11. Changes in Cover Types (1982 and 2002)

Source: Hink and Ohmart 1984; Reclamation 2004b,c

Statistical tests of significance were applied to evaluate the observed changes in relative cover of different vegetation types (Appendix L). The data indicate the following vegetation trends:

- The relative amounts of structural Types 1, 2, 5, and 6 declined by 36 percent, 2 percent, 4 percent, and 50 percent, respectively. Loss of native vegetation was particularly significant in each of these vegetation types.

- The relative amounts of structural Types 3 and 4 increased by 92 percent and 80 percent, respectively. Exotic and mixed exotic and native vegetation accounted for the increase observed in structural Type 3. Increases in native riparian vegetation occurred in Type 4, those dense intermediate height trees with little undergrowth that may provide important habitat for riparian songbirds.
- The relative amount of marshes/ponds increased slightly and bare ground/salt grass increased by just over 200 percent. Marshes and ponds support a wide variety of wildlife, but bare ground and salt grass areas do not.

3.3.2.2 Riparian Wildlife Resources

Wildlife Use of Riparian Zones within the Rio Grande Floodplain

Riparian ecosystems play a vital role in determining wildlife abundance and diversity in arid lands. The Rio Grande floodplain is significant to regional wildlife even though it is less than one percent of the land area of the upper Rio Grande basin (Finch et al. 1995). It also provides a valuable corridor for migratory birds and high-quality habitat for insects, amphibians, reptiles, birds, and mammals (Scurlock 1998).

From north to south in the project area, the riparian zones differ somewhat in wildlife abundance and in common species. There is a disproportionate amount of data available for the Central Section, and less published data available on wildlife use in the Rio Chama Section. Appendix J provides the available data on wildlife use in the different river sections.

Insect Use of the Rio Grande Floodplain

Terrestrial insects influence nutrient cycling and plant productivity and are prey species for both invertebrates and vertebrates (Ellis et al. 2001). A 1994–1997 study (Bess et al. 2002) found 80 species of spiders, beetles, isopods, and crickets on the floor of the bosque. Ellis et al. (2000) found 138 taxa from four sites and reported that a variety of ant species were also found in riparian ecosystems.

Amphibian and Reptile Use of the Rio Grande Floodplain

The distribution of several amphibian and reptile species is closely correlated to riparian vegetation communities. In their studies of wildlife use of Rio Grande riparian communities, Hink and Ohmart (1984) found amphibian and reptile capture rates were highest in areas of mixed cottonwood/coyote willow stands with sparse understory and small openings with little or no woody species (Type 2, 4, 6). Capture rates were lowest in sites with dense understories (Types 1, 3, 5), particularly in marshy, edge, and wooded areas.

Bird Use of the Rio Grande Floodplain

Birds are the most visible and, therefore, the most widely studied wildlife in the Rio Grande floodplain, which is utilized by over 60 percent of the bird species known to occur in New Mexico (Hink and Ohmart 1984). The most common breeding season species are mourning dove, black-chinned hummingbird, downy woodpecker, ash-throated flycatcher, white-breasted nuthatch, spotted towhee, black-headed grosbeak, and blue grosbeak. Common breeding raptors include great horned owl, western screech-owl, Cooper's hawk, and, in burned areas, American kestrel. Two federally listed threatened or endangered species, the bald eagle and the southwestern willow flycatcher, occur in the project area.

Generally, the abundance of breeding birds increases with the complexity and density of vegetation structure, which is thought to be related to the increased food, cover, or nest substrate it provides. Along the Rio Grande, the highest breeding densities typically were found in Type 1 and Type 5, regardless of whether vegetation is native or exotic (Hink and Ohmart 1984; Hoffman 1990; Thompson et al. 1994; Stahlecker and Cox 1996). Sparse understory bosque stands (Type 2) generally support fewer breeding birds, while Types 3 and 4 vary widely in breeding bird use.

The Rio Grande is a major migratory corridor for songbirds (Yong and Finch 2002), waterfowl, and shorebirds. Both the river channel and the drains adjacent to the bosque provide habitat for species such as mallards, wood ducks, great blue herons, snowy egrets, green herons, belted kingfishers, and black phoebes. Agricultural fields and grassy areas with little woody vegetation are important food sources for sparrows and other songbirds during migration and winter.

Mammal Use of the Rio Grande Floodplain

Hink and Ohmart (1984) found small mammal (anything smaller than a rat) capture rates were highest in sites where cottonwood and coyote willow were less than 40 feet tall and there was a relatively dense understory (Type 3). Capture rates were lowest in areas where trees were over 20 feet tall with limited understory vegetation (Type 4).

Large animals can significantly modify the structure and function of river corridors. Raccoons, domestic and feral dogs and cats were the most common large mammals identified. Also observed were porcupines, striped skunks, rock squirrels, pocket gophers, desert cottontails, coyotes, foxes, muskrat, beaver, and, to a lesser extent, bobcats. Mule deer were recorded from Cochiti Dam north, along the Rio Grande and Rio Chama. Domestic livestock are also common in riparian habitats, particularly on private and Pueblo lands. Many tree- and cave-dwelling bats were documented in the riparian areas of the Rio Grande. Populations around Elephant Butte Reservoir are associated with high insect populations. At least eight bat species, including pallid bat and Mexican free-tail bat, occur between San Acacia Diversion Dam and Elephant Butte Dam (Hink and Ohmart 1984).

3.3.2.3 Wetland Resources

Rio Grande Wetland Function and Types

Wetlands are defined as a transition zone between land and water, an area where the water table is at or near the surface or the land is covered by shallow water (Cowardin et al. 1979). Water saturation determines the nature of soil development and the types of plants and animals living in these habitats. Wetlands exhibit wetter soils and support more plant and animal species than the riparian zone along which they occur. They stabilize streambanks and provide storage areas for floodwaters, thereby protecting downstream areas. Wetlands function as important biological filters to trap sediment and nutrient run-off from surface water and upland environments. In addition, wetlands provide areas of greater biological diversity than the surrounding riparian and upland habitats, and provide breeding sites and wintering areas for numerous wetland-dependent wildlife species. They also serve as migratory stop-over areas for waterfowl and shorebirds.

The naturally vegetated areas within the floodplain of the Rio Grande are primarily composed of forested, shrub/scrub, emergent, palustrine, and lacustrine wetlands, as defined by the FWS (Cowardin et al. 1979). Some pockets of vegetation within the project area may have become disconnected from the active channel over time so that they no longer fit wetland criteria, but nearly all vegetation is dependent on groundwater and surface water for part of the growing season. The baseline vegetation survey using the modified Hink and Ohmart classification system roughly correlates with the Cowardin system of wetland classification in that Hink and Ohmart Types 1, 2, 3, and 4 are forested wetland types, Type 5 is comparable to shrub scrub wetland types; Type 6 and marshes are generally emergent wetlands. Channels, lakes and ponds are largely un-vegetated wetlands. In addition, many areas with riparian vegetation communities described in Section 3.3.2.1 may qualify as jurisdictional wetlands as defined in the 1987 *Corps of Engineers Wetlands Delineation Manual*, if they possess the required characteristics of hydric soils, hydrophytic vegetation, and hydrology (Corps 1987a).

As a result of the large extent of different wetland types within the project area, selected wetland complexes are described in **Table 3-4** with locations shown in **Map-3-5**. These wetland complexes were selected because they may be affected by the proposed changes in water operations. All wetland vegetation in the project area may be affected by the duration of high surface water flows. Flows greater than the 75th percentile contribute to groundwater recharge and the stability of groundwater elevations and may be used as an indicator of inundation frequency of wetlands on islands and in the overbank areas. Low flows in the river channel (less than the 25th percentile) reduce the capability of the river flow to maintain minimum ground water levels in adjacent wetlands.

Table 3-4. Selected Wetland Complexes Along the Rio Grande, with Approximate Acreages of Wetland Types

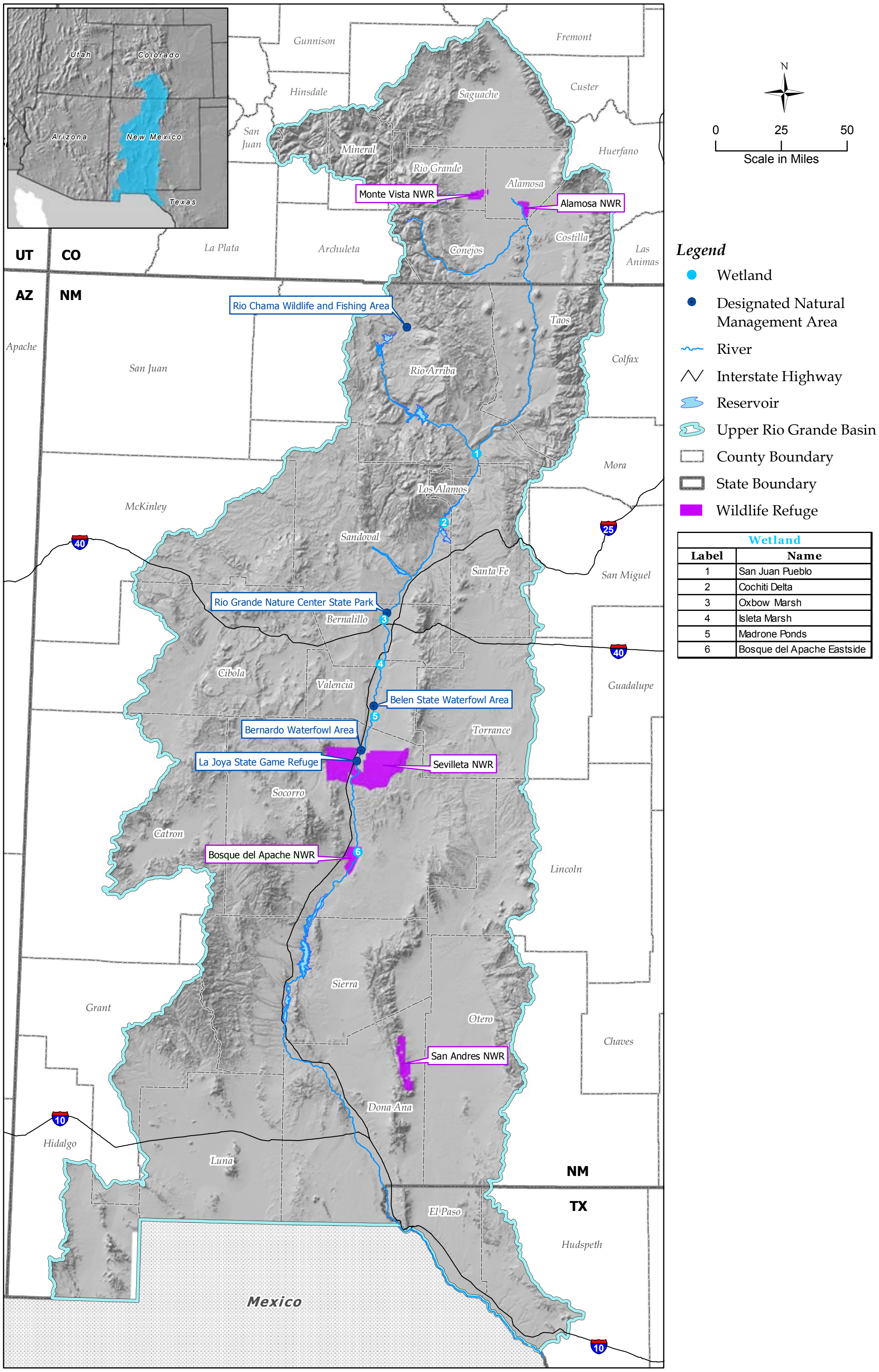
Wetland	Section	Open Water	Emergent Wetland	Shrub Wetland	Forested Wetland	Total
San Juan Pueblo	Northern	1	32	87	1	121
Cochiti Lake Delta	Rio Chama	245	24	159	—	428
San Antonio Oxbow	Central	7	36	20	2	65
Isleta Marsh	Central	12	225	126	35	398
Madrone Pond	Central	2	35	22	—	59
Bosque del Apache NWR (east bank)	San Acacia	15	141	317	12	485

Source: FWS 2003a

The water regime of these wetlands depends on proximity to the river channel and depth to groundwater. Most islands and point bars are periodically inundated by river flows and support meadow and shrub wetland communities, while side channels frequently support marsh vegetation. Surface water inundation also influences the development of backwater marshes and shrub wetlands, such as the delta of Cochiti Lake.

Most wetlands within the floodway developed in areas with a high groundwater table. Isolated wetlands, or those relatively far from the river, are typically only flooded during high snowmelt runoff, such as the natural wetlands along the east bank of the Rio Grande at Bosque del Apache NWR.

Abandoned channels or depressions deep enough to intersect the regional groundwater table often support the largest wetland complexes along the Rio Grande. River flows during the spring runoff period elevate the regional water table sufficiently to discharge into these wetlands. Those at Isleta Marsh and Madrone Pond are examples of large wetlands primarily influenced by groundwater discharge. Surface water during the spring runoff may also inundate portions of these wetlands, such as those bordering the channel at San Juan Pueblo. Surface water flow from arroyos may also support the wetland water regime, as at the San Antonio Oxbow (**Figure 3-12**).



1 **Map 3-5. Selected Wetlands, Wildlife Refuges, and Designated Natural Management Areas**

Figure 3-12. San Antonio Oxbow, Central Section

In addition to the relatively natural wetlands described here, very large and productive wetlands are maintained through intensive management at refuges and other areas outside the levees of the Rio Grande, including wetlands along the LFCC in the San Acacia Section.

Wildlife Refuges and Designated Natural Management Areas

National and State Wildlife Refuges and Designated Natural Management Areas were set aside with biological missions to protect and enhance biological conditions necessary to support numerous wildlife species. These areas in the Rio Grande floodplain, shown in **Table 3-5**, are dependent on surface and groundwater conditions supported by the water operations at facilities under consideration in this EIS. Map 3-5 shows the locations of these areas relative to the project area.

In addition to the lands set aside for wildlife protection and enhancement, there are some areas in which riparian restoration projects are established. These include the Santa Ana Pueblo Rio Grande Restoration Project, the Albuquerque Overbank Project, and the Los Lunas Riparian Project. These projects are described in Appendix L.

Table 3-5. National and State Wildlife Refuges and Designated Natural Management Areas in the Project Area

Name	Section	Size	Description
Alamosa National Wildlife Refuge	Northern	11,169 acres	Natural river bottom wetland, dissected by sloughs and oxbows of the river; wetland and wildlife habitat
Sevilleta National Wildlife Refuge	Central	229,700 acres	Habitats include bosque riparian forests and wetlands; supports four major ecological habitats; managed to maintain the natural processes of flood, fire, and succession that sustain this diverse ecosystem; vital to migrating birds and other wildlife
Bosque del Apache National Wildlife Refuge	San Acacia	57,191 acres	Waters of the Rio Grande have been diverted to create 7,000 acres of wetlands within total acreage of vital wildlife habitat
Rio Chama Wildlife and Fishing Area	Rio Chama	13,000 acres	On the Rio Chama, one of the state's larger and better trout streams (hatchery-stocked rainbow trout)
Rio Grande Nature Center State Park	Central	170 acres	Bosque located within the Central Flyway for migratory birds; wetlands and riparian wildlife habitat
Belen State Waterfowl Area	Central	230 acres	On Rio Grande bottomland; farmed to provide waterfowl feed and resting habitat
Bernardo Waterfowl Area	Central	1,573 acres	Includes 450 acres of crops cultivated to provide winter feed for migratory and upland birds; bird watching and hunting
La Joya State Game Refuge	Central	3,550 acres	Ponds, canals, and ditches in the Central Rio Grande Valley; wildlife and waterfowl protection; bird-watching and seasonal waterfowl hunting

Sources NMSP 2003; NMDGF 2003a,b;

3.3.3 Threatened, Endangered, and Special Status Species

3.3.3.1 Federally Listed Species and Critical Habitat Designations

As shown in **Table 3-6**, of the federally listed species protected under the Endangered Species Act (ESA) of 1973 (16 United States Code [U.S.C.] 1531-1544, as amended), only five have the potential to occur within the planning area. Three of these species have habitat preferences and behaviors that may be affected by changes to water operations on the Rio Grande: Rio Grande silvery minnow, southwestern willow flycatcher, and bald eagle. Candidate species are not included because they are not afforded protection under the ESA.

Table 3-6. Summary Information on Federally Listed Species in the Project Area

Common Name	Federal Status	River Sections/ Reaches	Season and Habitat Preference
Rio Grande silvery minnow	Endangered	Central and San Acacia; Reaches 10–14	Stream margins, side channels, and off-channel pools where water velocities are low or reduced from main-channel velocities
Southwestern willow flycatcher	Endangered	ALL: Alamosa, Colorado to Ft. Quitman, Texas; Reaches 1–17	Breeding habitat consists of large stands of dense willow and cottonwood with seasonal adjacent surface water
Bald eagle	Threatened	ALL: Alamosa, Colorado to Ft. Quitman, Texas; Reaches 1–17	Wintering roosts in large trees near perennial water
Interior least tern	Endangered	San Acacia and Southern; Reaches 14–17	Occasional migrants have been observed at Bosque del Apache NWR
Brown pelican	Endangered	San Acacia and Southern; Reaches 14–17	A rare, non-breeding visitor to portions of the project area

Source: FWS 2005

The endangered interior least tern and brown pelican are occasional or rare migrants within the project area and therefore will not be addressed further. Federal candidate species relevant in the project area include, Gunnison's sage-grouse (*Centrocercus minimus*) and boreal toad (*Bufo boreas boreas*) listed in Colorado; the yellow-billed cuckoo (*Coccyzus americanus*) listed in Colorado, New Mexico, and Texas; and the black-tailed prairie dog (*Cynomys ludovicianus*) listed in New Mexico although it is considered extirpated from the state (NMDGF 2004a).

Rio Grande Silvery Minnow

The RGSM (*Hybognathus amarus*) was formerly one of the most widespread and abundant species in the Rio Grande basin of New Mexico, Texas, and Mexico (Bestgen and Platania 1991). At the time of its listing as endangered, the silvery minnow was restricted to the Central and San Acacia Sections, occurring only from Cochiti Dam downstream to the headwaters of Elephant Butte Reservoir, which is only 5 percent of its historic range (Platania 1991). FWS cited several factors responsible for declines in silvery minnow population including: drying of portions of the Rio Grande below Cochiti Dam; construction of mainstem dams; introduction of non-native competition/predator species; and degradation of water quality (FR 1993).

PHOTO: NMDGF

The RGSM was listed as federally endangered under the ESA in July 1994. The species is listed by the State of New Mexico as an endangered species, Group II (NMDGF 2004c). On February 19, 2003, the final rule designated critical habitat along the Rio Grande corridor from New Mexico Highway 22 Bridge (immediately downstream from Cochiti Dam) to the utility line crossing the Rio Grande, a permanent identified landmark in Socorro County, New Mexico, a distance of approximately 170 miles. This designation became effective March 31, 2003 (FR 2003). Constituent elements of critical habitat required to sustain the RGSM include stream morphology that supplies sufficient flowing water to provide food and cover needs for all life stages of the species; water quality to prevent water stagnation (elevated temperatures, decreased oxygen, etc.); and water quantity to prevent formation of isolated pools that restrict fish movement, foster increased predation by birds and aquatic predators, and congregate disease-causing pathogens (FWS 1999).

The RGSM is a moderately sized, stout minnow, reaching 3.5 inches in total length. It spawns in the late spring and early summer, coinciding with spring snowmelt flows (Sublette et al. 1990). Spawning also may be triggered by other flow events such as spring and summer thunderstorms. This species spawns by dispersing its eggs into the current that then drift downstream (Platania 1995). As egg development occurs during the drift, which may last as long as a week depending on temperature and flow conditions, the larvae seek quiet waters in eddys and channel margins. Considerable distance could be traversed by the drifting, developing eggs (Sublette et al. 1990; Bestgen and Platania 1991; Platania 1995; Platania and Altenbach 1998). Maturity for this species is reached toward the end of the first year. Most individuals of this species live one year, with only a very small percentage reaching age two. It appears that the adults die after spawning (Sublette et al. 1990; Bestgen and Platania 1991).

Because of upstream channel incision (habitat degradation) and downstream transport of RGSM eggs and larvae, a greater abundance of the species occurs in the San Acacia Section, as documented by fish sampling (Bestgen and Platania 1991; Platania 1993). Based on fish surveys in the late 1990s, over 95 percent of the collected RGSMs occurred downstream of San Acacia Diversion Dam (Dudley and Platania 1999; Smith and Jackson 2000). More recent monitoring surveys found that an increasing number of minnows are being captured above the San Acacia reach (Dudley et al. 2004).

Natural habitat for the RGSM includes stream margins, side channels, and off-channel pools where water velocities are lower than in the main channel. Areas with debris and algal-covered substrates are preferred. The sides of islands and debris piles often serve as good habitat (Sublette et al. 1990; Bestgen and Platania 1991).

Southwestern Willow Flycatcher

PHOTO: NMDGF

The southwestern willow flycatcher (*Empidonax traillii extimus*), or SWFL, is a riparian obligate and nests in riparian thickets associated with streams and other wetlands where dense growth of willow, buttonbush, box elder, Russian olive, saltcedar or other plants are present. Breeding territories occur in dense riparian vegetation, often within 50 meters of water, in stands that were created, or are maintained by, periodic overbank flooding. Along the Rio Grande, nests have been consistently found within 150 feet of surface water, typically river channels, sloughs, backwaters, and beaver ponds. The flycatcher is a late spring/summer breeder that nests in late May through July and fledges young from late June to early August (FR 1995a). The SWFL is federally listed as an endangered subspecies under the ESA.

Table 3-7 provides summary information on the number of known SWFL territories active since 2000 relative to Recovery Unit goals. The distribution of the species is not uniform in the planning area. Territories usually occur in clusters along the riparian corridor within approximately 10 miles of each other. Flycatchers return to these “sites” with great fidelity to establish territories and nests year after year. The size of each territory averages approximately 2.7 acres (FWS 2002a) and surface water hydrology has a strong influence on nest location.

Critical habitat designation for SWFL is effective as of November 18, 2005 (FR 2005) and followed a seven-month public comment period on the proposed rule that ended on May 31, 2005. New Mexico is one of five states included in the potential habitat designation. Lands identified as essential for the species fall within existing Recovery and Management Units.

The 2002–2003 vegetation survey quantified vegetation used by SWFL. Surveys for both vegetation and SWFL show that the species occupies territories and builds nests predominantly in Hink and Ohmart Types 3 and 4 and less frequently in Types 1 and 5 vegetation. No nests were identified in Type 2 vegetation. Native overstory with dense native understory vegetation was the predominant vegetation at nest locations, accounting for 78 percent of all nest locations and territories. A more recent study (Moore and Ahlers 2004) shows that there is a definite preference for willow-dominated habitats.

The structural composition and stem/twig density required by SWFL is developed and sustained by high frequency and duration of flooding. Breeding SWFLs exhibit a strong affinity for moist soils maintained by spring flooding and high groundwater levels in the overbank areas as well as for nearby availability of open water.

Active flycatcher territories are found in several locations in the planning area. Over 158 active territories were identified during intensive surveys in 2002 and 2003 (Moore and Ahlers 2003; Ahlers and Moore 2004; Stone 2003). The Rio Chama Section survey identified only one SWFL territory. Reach 7 contains 2,310 acres of mapped vegetation, of which 333 acres (14 percent) are suitable habitat for SWFL, and 137 acres (6 percent) of the total surveyed vegetation are located within 10 miles of the nearest active flycatcher territory.

The Central Section survey identified 21 active SWFL territories, primarily in Reach 13. The Central Section has 11,710 acres of riparian vegetation. Of that amount, 942 acres (8 percent) of suitable flycatcher habitat are within 10 miles of occupied territories and 1,468 acres (13 percent) are more than 10 miles from existing territories.

Known flycatcher territories in the San Acacia Section are concentrated in areas south of Bosque del Apache NWR, many of which are located within the delta upstream of Elephant Butte Reservoir. A total of 2,247 acres of suitable habitat, 8 percent of the total mapped vegetation, occur in this section. Of the suitable habitat, 1,374 acres (61 percent) occur within 10 miles of occupied territories. Surface water hydrology has a strong influence on nest location. Ninety-seven percent of nests identified in the San Acacia Section from 1999-2003 were located within 164 feet of surface water when the site was first occupied. The average distance from an active nest to surface water was 78 feet.

In New Mexico, the Rio Grande Recovery Unit includes two river segments that lie within the planning area. The proposed Upper Rio Grande Management Unit extends 46 miles from the Taos Junction Bridge (State Route 520) downstream to the Otowi Bridge (State Route 502). The Middle Rio Grande Management Unit extends 129 miles, beginning 4.2 miles north of the intersection of Interstate Highways 25 and 40 downstream to the overhead powerline near Milligan Gulch at the northern end of Elephant Butte State Park (FR 2004). Progress toward meeting recovery goals in the Rio Grande Recovery Unit has been variable, as shown in Table 3-7. The Middle Rio Grande Recovery Unit is the most likely to be affected by changing operations from the Project. This unit has met or exceeded its goals, to date, for recovery of SWFL and maintenance of quality habitat, primarily in the San Acacia Section.

Table 3-7. Known Abundance and Distribution of Southwestern Willow Flycatcher Territories and Habitat in Rio Grande Recovery Units (2002-2004) Recovery Plan Goals (FWS 2002a)

River Section	Rio Grande SWFL Recovery Management Unit	River Reaches with Known Territories	Known Active SWFL Territories	Recovery Goal Territories	Recommended Acres Suitable SWFL Habitat to Meet Recovery Goal	Acres of Suitable SWFL Habitat[1] (% mapped vegetation)	Progress Toward Recovery Goal
Northern Section (Reaches 1,2)	San Luis Valley	1,2	40–65*	50	271	Not mapped	Goal met; availability unknown
Northern Section (Reaches 3,4,8,9)	Upper Rio Grande Unit	4	12**	75	407	172 5% (Reach 4 only)	Goals not met; habitat may be adequate
Rio Chama Section		8	1			137 5% (Reach 7 only)	
Central Section	Middle Rio Grande Unit	13	10**	100	543	942 5%	Goals met; habitat abundant
San Acacia Section		14	149**			1,374 7%	
Southern Section	Lower Rio Grande Unit	16	6*	25	136	Not mapped	Goals not met; habitat availability unknown

[1] All suitable habitat within 50 meters of open water and within 10 miles of occupied sites.
*Moore and Ahlers 2003; **Moore and Ahlers 2004; Stone 2003

Bald Eagle

The FWS reclassified the bald eagle (*Haliaeetus leucocephalus*) from endangered to threatened on July 12, 1995 (FR 1995b). In 1999, the FWS proposed the bald eagle be removed from the list of Threatened and Endangered Wildlife (FR 1999). Wintering bald eagles frequent all major river systems in New Mexico from November through March, including the Rio Grande. Bald eagle prey includes fish, waterfowl, and small mammals. Bald eagles prefer to roost and perch in large trees near water. Suitable perch sites occur within the project area, typically where large cottonwoods occur at the river's edge or in large snags near reservoirs. The main threats to New Mexico's wintering bald eagle population are impacts to their prey base and availability of roost sites.

3.3.3.2 Special Status State-Listed Species and Other Species of Concern

The states of Colorado, New Mexico, and Texas recognize additional threatened, endangered, or special status species not listed under the ESA. In Appendix L, 136 species are listed, several of which may appear more than once (e.g., threatened in Colorado and as a species of concern in New Mexico). Most of these species were removed from further consideration within this EIS because they: (1) have not been found at all in the project area; (2) are not a riparian/wetland species and therefore not affected by water operations; or (3) are an uncommon migrant that occurs outside the project area. As a result, impact would be negligible to nonexistent. **Table 3-8** shows only those species currently endangered in Colorado, New Mexico, or Texas. Any of these species that are also federally listed are described above in the Federally Listed Species section of this chapter.

Table 3-8. State-Endangered Species Possibly Found in the Project Area

SPECIES	State Status			Standing			
Common / Scientific Name	**CO**	**NM**	**TX**	**1**	**2**	**3**	**4**
PLANTS							
Pecos sunflower (*Helianthus paradoxus Heiser*)	—	E	—	—	□	—	—
FISH							
Rio Grande silvery minnow (*Hybognathus amarus*)	—	E	—	■	—	—	—
AMPHIBIANS and REPTILES							
Western boreal toad (*Bufo boreas boreas*)	—	E	—		—	□	—
BIRDS							
American peregrine falcon (*Falco peregrinus anatum*)	—	T	E	■	—	—	—
Brown pelican (*Pelecanus occidentalis carolinensis*)	—	E	—	—	—	—	□
Common ground dove (*Columbina passerina pallescens*)	—	E	—	—	—	□	—
Interior least tern (*Sterna antillarum athalassos*)	—	E	—	—	—	—	□
Northern aplomado falcon (*Falco femoralis septentrionalis*)	—	E	E	—	—	□	—
Piping plover (*Charadrius melodus circumcinctus*)	—	E	—	—	—	—	□
Southwestern willow flycatcher (*Empidonax traillii extimus*)	E	E	E	■	—	—	—
White-tailed ptarmigan (*Lagopus leucurus altipetens*)	—	E	—	—	—	□	—
Whooping crane (*Grus americana*)	E	E	E	—	—	—	□
MAMMALS							
Black-footed ferret (*Mustela nigripes*) ►	E	—	E	—	—	□	—
New Mexico meadow jumping mouse (*Zapus hudsonius luteus*)	—	T	—	■	—	—	—
Botta's pocket gopher (*Thomomys bottae*)	E	—	—	—	□	—	—
Canada lynx (*Lynx canadensis*)	E	—	—	—	—	□	—
Desert bighorn sheep (*Ovis canadensis mexicana*)	—	E	—	—	—	□	—
Gray wolf (*Canis lupus*) ►	—	—	E	—	—	□	—
Wolverine (*Gulo gulo*) ►	E	—	—	—	—	□	—

■ Will be further evaluated because species may receive possible affects
□ Will be removed from further consideration because species is:
- not in project area
- not a riparian/wetland species and therefore not affected by water operations
- an uncommon migrant with distribution outside project area—effects negligible

► Believed to be extirpated from area
E = Endangered; T = Threatened
Source: FWS 2003b; NMDGF 2004a

Rio Grande Silvery Minnow (*Hybognathus amarus*)

See Federally Listed Species section.

American Peregrine Falcon (*Falco peregrinus anatum*)

The peregrine falcon is an FWS Species of Concern and a New Mexico Threatened species. This raptor nests in the canyons upstream of Cochiti Reservoir and frequently hunts for waterfowl along the Rio Grande corridor. The Santa Fe National Forest identified nest sites within the canyons adjacent to the Rio Grande (NMDGF 2004b).

Southwestern Willow Flycatcher (*Empidonax traillii extimus*)

See Federally Listed Species section.

Yellow-billed Cuckoo (*Coccyzus americanus*)

The western population of the yellow-billed cuckoo experienced a severe decline in distribution and abundance throughout the western United States. This is a federally listed candidate species. Candidate species have no formal protection under the ESA, but are considered in this document for planning purposes. This species prefers riparian habitat with dense willow and cottonwood, but non-natives like saltcedar are also used (FR 2001). Nesting territories are located in dense or narrow saltcedar stands or mixed saltcedar/willow habitat.

New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*)

The meadow jumping mouse is an NMDGF Threatened species and is considered a Species of Concern. It requires dense vegetation to persist and typically occupies marshes, moist meadows, and riparian habitats. The species has recently been found occupying constructed habitats such as irrigation drains and canals, and many question whether the species is threatened by habitat destruction. The meadow jumping mouse is found in the Northern, Rio Chama, Central and San Acacia Sections. Reports indicate that the key habitat areas for the species include wetlands in the Española, Rio Cebolla, Isleta Marsh, and Bosque del Apache NWR (NMDGF 2001).

3.3.4 Biodiversity

Biodiversity is defined in several different ways. Ecologists focus on the species level and define species diversity as (1) the quantity of species in any given community (species richness) and (2) the relative abundance of different species (species evenness) within the community (Molles 1999). All plant, insect, and wildlife species have not only adapted to the environmental conditions in which they live, but are also intricately connected to all other living creatures. When environmental conditions change, not only are some species lost altogether, but the established interactions between remaining species are disrupted.

Changes in biodiversity along the Rio Grande have been documented since the turn of the 20th century (e.g., Scurlock 1998). Such changes result from multiple complex factors including physical modifications, water operations, and geomorphic change. Natural events such as drought, violent weather patterns, or disease can cause considerable change at the ecosystem level, affecting biodiversity.

3.4 Water Quality

3.4.1 Regulations Protecting Water Quality

The Clean Water Act (formally titled the Federal Water Pollution Control Act, 33 U.S.C. §1251, as amended) and various state regulations, such as the New Mexico Water Quality Act, require the development of water quality standards to protect public and private interests, wildlife, and the quality of waters. Within the project area there are three states (Colorado, New Mexico, and Texas) and 10 Pueblos (Taos, San Juan, Santa Clara, San Ildefonso, Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, and Isleta) with distinct jurisdictional boundaries and direct concerns related to water quality in the project area. Within these boundaries, water quality is regulated by standards from each of the three states, the Rio Grande Compact, and four of the Pueblos (San Juan, Santa Clara, Sandia, and Isleta). The remaining

Pueblos have either not developed explicit water quality standards or the U.S. Environmental Protection Agency (EPA) has not yet adopted their standards.

Each set of regulations has numeric, narrative (or general), and antidegradation standards to ensure the quality of water. Numeric standards provide a known threshold with which water quality conditions can be compared and are set for constituents that can be quantified and for which accurate background conditions have been established. Antidegradation standards can be applied to all waters with or without numeric standards. Antidegradation standards were developed to ensure that waters are not degraded beyond their current condition unless otherwise authorized. When water bodies are not in compliance with these standards or numeric or narrative standards have been exceeded, water bodies are subject to enforcement actions under Clean Water Act sections 303(d) and 305(b).

3.4.2 Water Quality Assessment

Applicable state, tribal, and compact standards and jurisdictional boundaries were reviewed within the five river sections. Boundaries of these reaches were set either when a change in water quality regulations or land governance occurred, or when waters entered or left a reservoir. A more detailed discussion of water quality reaches and subreaches, regulatory standards, and agency jurisdiction is provided in Appendix M.

Water quality resource indicators were developed by assessing data availability in the project area and by identifying specific water quality constituents most likely to be affected by reservoir operations. Generally, only constituents with numeric standards were selected as indicators. However, additional constituents were included if it was determined that they posed a specific human health threat, were uniquely influenced by reservoir operations, or were subject to antidegradation standards. The following water quality resource indicators were evaluated: water temperature, dissolved oxygen, suspended sediments/turbidity, total dissolved solids (TDS), pH and arsenic. Dissolved hydrogen sulfide in and downstream from reservoirs was also evaluated.

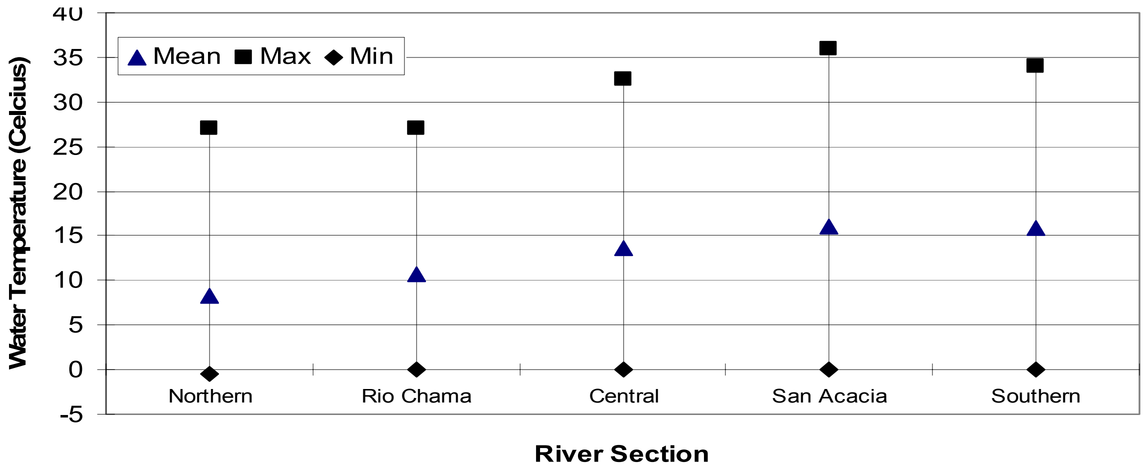
3.4.3 Trends in Water Quality Conditions

The water quality assessments summarized in Appendix M are based upon a database containing water quality records for the Rio Grande, its tributaries, and mainstem reservoirs that was compiled from sources including U.S. Geological Survey (USGS), EPA, USIBWC, and NMED. Data collected after 1975 and subjected to standard quality control practices were utilized. Two reservoirs (Abiquiu and Cochiti Reservoirs) and 18 USGS gages were selected for detailed analysis based on data availability at those sites and their locations within the basin. Generally, water temperature, dissolved oxygen, TDS/conductivity, and pH datasets were adequate for analysis. Arsenic, turbidity/suspended sediment, mercury, and hydrogen sulfide datasets were extremely limited with small amounts of data present at a few select gages. The remaining reservoirs and gage locations in the basin were not selected for further evaluation due to the lack of suitable water quality data. See Appendix M for a listing of gage locations by river section, more detailed water quality data, and a description of the methodology used.

3.4.3.1 Water Temperature

Each of the selected gages has sufficient water temperature data to establish baseline conditions from 1975 to 2003. Overall, temperature increased latitudinally, from north to south, throughout the system (**Figure 3-13**). The highest water temperatures in the system occurred during summer months in the Central, San Acacia, and Southern Sections. Lowest water temperatures were recorded in Northern and Rio Chama Sections during winter months. All sections exhibited highest water temperatures in summer months when air temperatures were highest. Analyses demonstrated that water temperature is highly correlated with air temperatures at most locations in the upper Rio Grande basin.

Figure 3-13. Mean, Maximum, and Minimum Water Temperature by River Section (1975-2003)



Slight differences in maximum temperatures were observed below Elephant Butte Reservoir. These data indicate that maximum summer temperatures were approximately 8 degrees Celsius lower below the dam than in the reservoir inflow near San Marcial. However, the average and minimum temperatures were not noticeably different. There was no noticeable difference between water temperatures at inflows and outflows of the remaining reservoirs.

3.4.3.2 Dissolved Oxygen

Concentration of dissolved oxygen in water is dependent on water temperature and atmospheric pressure. Dissolved oxygen levels are affected by three primary mechanisms: diffusion from surrounding air, oxygen production during photosynthesis, and aeration caused by natural and artificial turbulence processes. All gages, with the exception of the gages immediately above and below Abiquiu Reservoir, had sufficient data to establish baseline conditions. Dissolved oxygen varies greatly by season, with the lowest dissolved oxygen values were directly correlated with higher air and water temperatures. Highest average dissolved oxygen levels were recorded in the Northern Section (**Figure 3-14**).

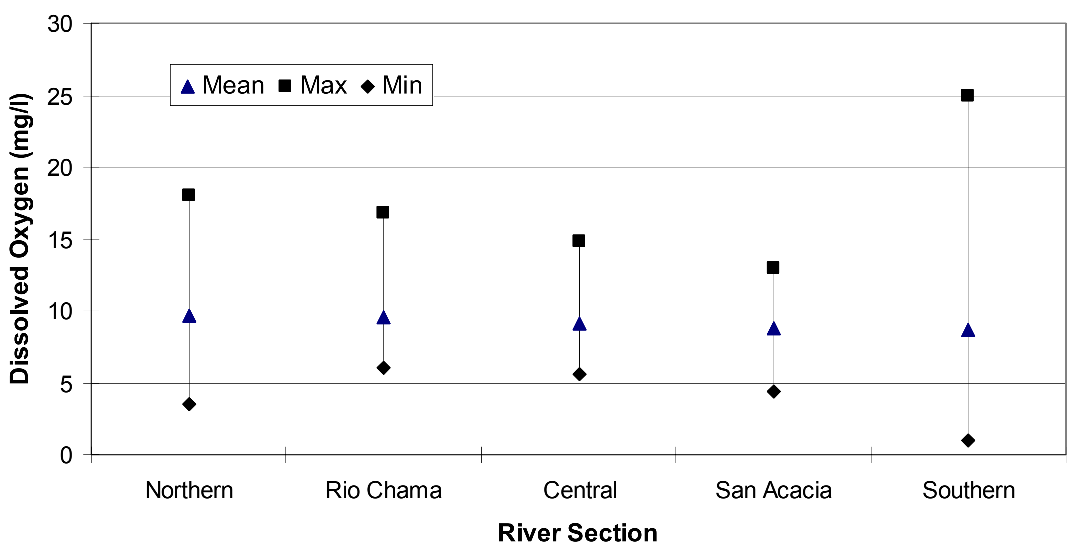


Figure 3-14. Mean, Maximum, and Minimum Dissolved Oxygen by River Section (1975-2003)

Trends in dissolved oxygen concentrations measured at the gage below Elephant Butte Dam were noticeably different from those observed at the other gage locations in the project area. During winter months, the Elephant Butte gage exhibited the highest average dissolved oxygen concentrations in the basin, but had the lowest dissolved oxygen concentrations during summer and fall months. Average dissolved oxygen concentrations during summer months below Elephant Butte Reservoir were more than 50 percent less than those measured at the San Marcial gage during the same period. No other gages had average dissolved oxygen concentrations below 7.2 milligrams per liter (mg/l).

3.4.3.3 Total Dissolved Solids

TDS are comprised of dissolved organic matter, salts, and minerals and metals originating from both natural and human-caused sources. Human-caused impacts include increased evapotranspiration rates from reservoirs, leaching of agricultural chemicals, and wastewater effluent. Natural sources include mineral dissolution and natural water cycle phenomena such as precipitation and evapotranspiration (Moore and Anderholm 2002).

TDS are highest in the Southern Section and lowest in the Northern Section (**Figure 3-15**). Gages in the Northern and Rio Chama Sections have relatively low TDS (100-300 mg/l). TDS starts to increase in the Central Section, with higher values identified at the Jemez River gage and below the Albuquerque gage. There is a slight seasonal increase at the Bernardo gage but values increase considerably in the San Acacia Section. The greatest TDS concentrations occur during summer and fall months with lowest average TDS values detected during snowmelt runoff.

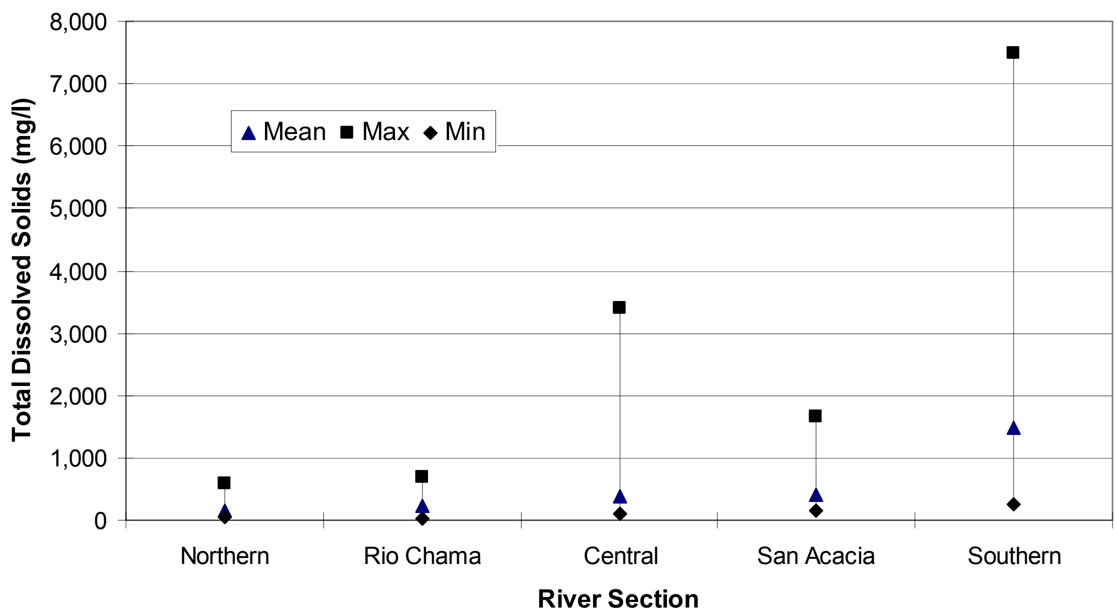


Figure 3-15. Mean, Maximum, and Minimum Total Dissolved Solids by River Section (1975-2003)

3.4.3.4 pH

Sufficient data exist for establishing baseline conditions for pH at all selected locations with the exception of the Above and Below Abiquiu Reservoir gages. Average pH values did not change between gages in the basin. Average pH for all gages was 8.1 (the minimum was 8.0 at LFCC near San Acacia, the maximum was 8.3 at Leasburg). Very few relationships were evident between pH and other water quality constituents. However, pH was strongly correlated with dissolved oxygen at Elephant Butte. When dissolved oxygen decreased at the Elephant Butte gage, a corresponding decrease in pH (an increase in acidity) was evident.

3.4.3.5 Turbidity/Suspended Sediments

Turbidity varies by season and latitude throughout the system. The lowest values occurred in the Northern and Rio Chama Sections between November and February; the highest values occurred in the Central and San Acacia Sections during summer months when runoff from storm events can rapidly increase river discharge and increase turbidity and sediment loads.

Reservoirs have an obvious influence on suspended sediment and turbidity levels with noticeable differences observed downstream of Abiquiu, Cochiti, and Elephant Butte Reservoirs. Reservoirs sequester the turbid and suspended sediment rich waters and allow the suspended loads to settle to the reservoir bottom preventing their movement downstream.

3.4.3.6 Fecal Coliform

Data for fecal coliform loads are limited in the project area. However, the loads follow the same general pattern as is exhibited by turbidity/suspended sediments. Generally, fecal coliform concentrations are highest following natural inflows from summer storm events. These events mobilize fecal material from upland sources and transport them to the rivers. During winter and spring runoff events, fecal coliform concentrations may be limited by low water temperatures. Reservoirs act as a sink for fecal loads with noticeable decreases in the mean values downstream from both Cochiti and Elephant Butte Reservoirs.

3.4.3.7 Arsenic

Arsenic contamination usually occurs in groundwater rather than in surface water. However, arsenic can be detected in surface water as a result of either natural or human-caused sources. Natural sources of arsenic include minerals that may leach arsenic into surface water and groundwater. Human-caused sources include pesticides, industrial compounds, and fertilizers. Arsenic data were limited throughout the river sections. However, the limited data suggest that arsenic loads remain consistent throughout the year with little seasonal variation. Arsenic concentrations were highest in the Rio Jemez and may contribute to increased arsenic loads downstream in the Central and San Acacia Sections. Arsenic concentrations in the Northern and Rio Chama Sections are lower than those found below Cochiti Reservoir.

3.4.3.8 Mercury

Insufficient data exists to establish conditions of mercury in the surface waters within the project area. Most of the mercury in surface water is likely associated with atmospheric deposition or natural background levels. Some human-caused sources of mercury, such as metal processing, medical wastes, or atmospheric deposition related to coal-burning, may also be important in the basin (USGS 2000a).

3.4.3.9 Hydrogen Sulfide

Very few data were identified for hydrogen sulfide. However, recent studies on Elephant Butte Reservoir (Canavan 1999) indicate that hydrogen sulfide is problematic during summer months when deeper portions of the reservoir become starved for oxygen. Conditions suitable for the generation of hydrogen sulfide may only occur when the reservoir is at relatively high storage levels and mixing does not occur in the lower levels of the water column. Releases of waters with high levels of hydrogen sulfide may contribute to the lower pH levels observed below the dam when dissolved oxygen levels are low. When hydrogen sulfide comes in contact with oxygen in the outlet works of Elephant Butte, it may react with the oxygen and produce low levels of sulfuric acid, causing a corresponding decrease in pH.

3.4.3.10 Other Water Quality Concerns

Many communities located along the Rio Grande discharge their treated wastewater effluent into the river. This effluent is regulated by 40 CFR 122, the Clean Water Act. Although the treatment facilities are located outside the levees, the effluent discharge pipelines are typically located within the floodplain. Flow alterations, defined broadly by the alternatives in this EIS and again in future actions, may affect these outfall structures. As future actions become defined and proposed, the impacts to these outfall structures and effluent discharge will be carefully evaluated.

3.5 Indian Trust Assets

Indian Trust Assets (ITAs) are defined as legal interests in assets held in trust by the federal government for Indian Tribes or individual tribal members. Examples of ITAs are lands, minerals, water rights, other natural resources, money, or claims. An ITA cannot be sold, leased, or otherwise transferred without the approval of the federal government. For a proposed action, federal agencies, in cooperation with any tribe affected by a project, must inventory and evaluate any assets held in trust. These responsibilities include the following:

- To recognize and fulfill their legal obligation to identify, protect, and conserve the trust resources of federally recognized Indian Tribes and tribal members (the term “Tribes” include Pueblo Indians).
- To consult with pueblos and tribes on a government-to-government basis for plans or actions that could affect tribal trust resources, trust assets, or tribal health and safety.

Native Americans use the Rio Grande for traditional and cultural purposes. Many pueblos and tribes have implemented habitat restoration projects along the river and are committed to protecting the river and riparian ecosystem. The trust resources identified through consultation meetings and correspondence as being of concern for this EIS include water flows, water quality, cultural resources, and riparian areas within the tribal lands. Water storage for prior and paramount lands is not subject to the restrictions dictated in the Rio Grande Compact.

3.6 Cultural Resources

Among the cultural resources known in the project area are archaeological sites, historic and prehistoric buildings, potential cultural landscapes, and traditional cultural properties (TCP), as discussed below. They are of concern based on numerous laws and mandates, including the National Historic Preservation Act, Archaeological Resources Protection Act, and Native American Graves Protection and Repatriation Act. More detail on cultural resources is provided in Appendix O.

3.6.1 Types of Cultural Resources

3.6.1.1 Archaeological Sites and Historic Buildings

The New Mexico Archaeological Records Management System (NMARMS) and the Colorado Historical Society databases were queried for information regarding cultural resources in the project area. More than 6,800 prehistoric and historic archaeological sites are known in the New Mexico portion of the project area (NMARMS 2002). It is estimated that over 480 sites are known in the Colorado portion of the project area.

3.6.1.2 Cultural Landscapes

It is difficult to determine whether cultural landscapes—Native American, Spanish, or Anglo—will emerge as important in the project area. However, recent changes in zoning regulations in Rio Arriba County now protect agricultural lands, suggesting that such lands may constitute Spanish cultural landscapes in the statutory sense of the term. Similarly, it is likely that certain parts of the project area may be deemed cultural landscapes by Native American communities.

3.6.1.3 Traditional Cultural Properties

The following general classes of TCPs occur within the project area.

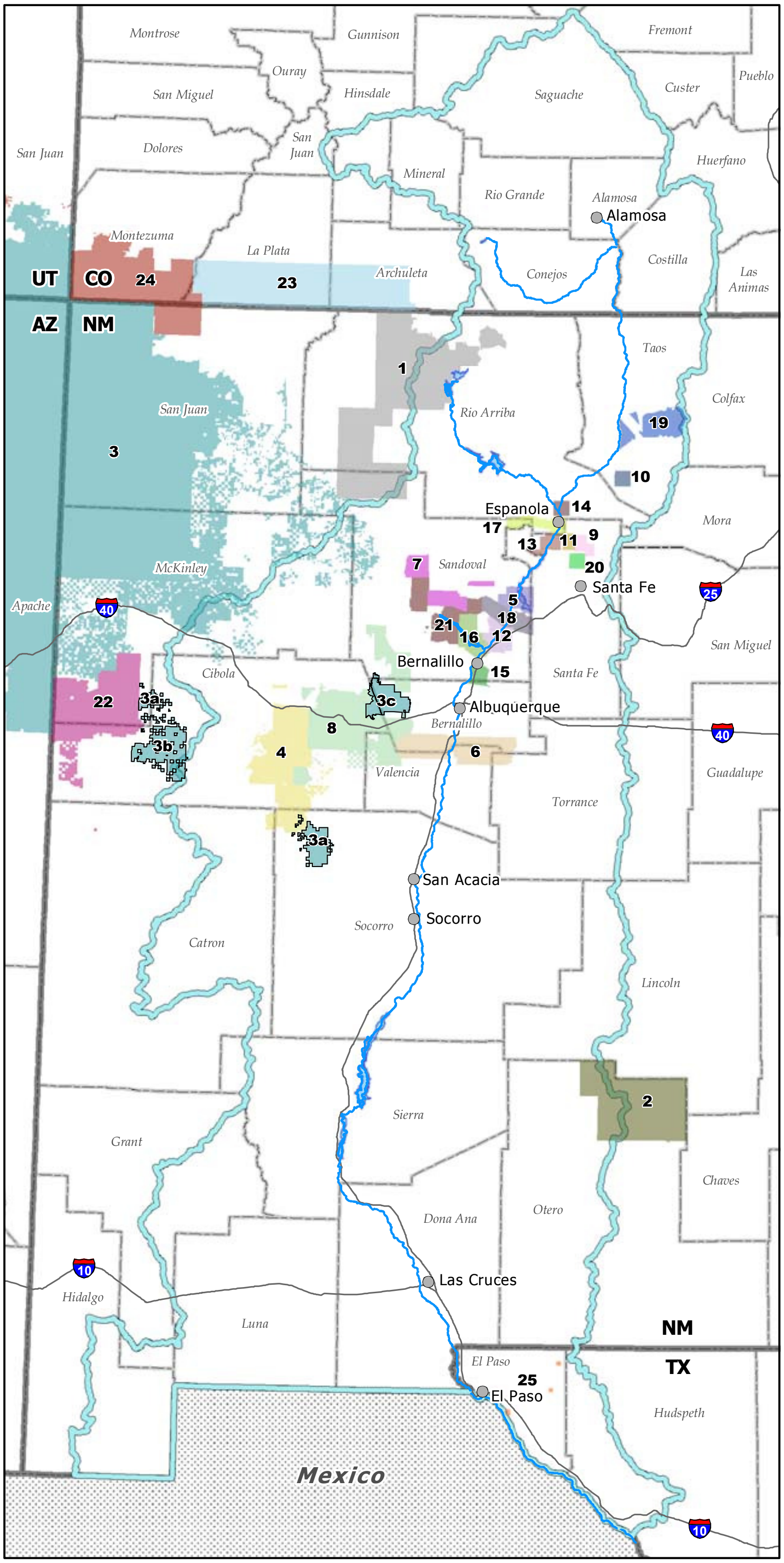
- New Mexico acequias have been determined by the New Mexico Office of Cultural Affairs, Historic Preservation Division, to be eligible for inclusion on the National Register of Historic Places (NRHP) as TCPs.
- Sites sacred to New Mexico's Native American communities are eligible for inclusion on the NRHP as TCPs.
- Other, as yet unknown, TCPs may emerge. For example, reaches of the Rio Grande containing certain kinds of plants may be found to be TCPs, since these plants are used in religious and other ceremonies.

Culture History

While cultural resources occur throughout the basin, specific cultural resources site survey information was retrieved from the New Mexico ARMS database along a 5-km buffer bordering the Rio Chama and Rio Grande (NMARMS 2002). Current boundaries of sovereign lands within the basin are displayed on **Map 3-6**.

Prehistory

The project area contains evidence of prehistoric occupations designated by archaeologists as "Anasazi" and "Mogollon," a distinction predicated on differences in ceramics, architecture, and other archaeological evidence. Generally, the northern sections of the project area contain remains typical of Anasazi occupations, while Mogollon occupations are typical of the southern sections. The term "occupations" recognizes that many sites (i.e., locations) may contain evidence of occupations spanning substantial periods of time. Included are phase sequences for the San Juan, Middle Rio Grande, Gallina, Rio Abajo, and Jornada portions of the project area. These regional phase sequences are then contrasted with the more generalized Pecos sequence that was used during the early years of archaeological investigations across the region. The term "site" refers specifically to a bounded geographic location that contains evidence of past human occupations.



Label	Name	Chapter
1	Jicarilla Apache Tribe	
2	Mescalero Apache Tribe	
3	Navajo Nation	
3a	Navajo Nation	Alamo
3b	Navajo Nation	Ramah
3c	Navajo Nation	To'Ha'ji'lee
4	Pueblo of Acoma	
5	Pueblo of Cochiti	
6	Pueblo of Isleta	
7	Pueblo of Jemez	
8	Pueblo of Laguna	
9	Pueblo of Nambe	
10	Pueblo of Picuris	
11	Pueblo of Pojoaque	
12	Pueblo of San Felipe	
13	Pueblo of San Ildefonso	
14	Pueblo of San Juan	
15	Pueblo of Sandia	
16	Pueblo of Santa Ana	
17	Pueblo of Santa Clara	
18	Pueblo of Santo Domingo	
19	Pueblo of Taos	
20	Pueblo of Tesuque	
21	Pueblo of Zia	
22	Pueblo of Zuni	
23	Southern Ute Tribe	
24	Ute Mountain Ute Tribe	
25	Ysleta del Sur Pueblo	

Map 3-6. Sovereign Lands in the Upper Rio Grande Basin

PaleoIndian (10,000 B.C. to 5000 B.C.)

PaleoIndian sites have been found in a variety of settings, reflecting highly mobile hunting groups. These are generally along the margins of small ephemeral lakes, along ridge lines paralleling large drainages, and immediately adjacent to the main stem of the Rio Grande (Marshall and Walt 1984; Scheick 1996). Seventeen sites with Paleo-Indian occupations occur in the planning area, constituting approximately 0.2 percent of the total number of identifiable time-sequent occupations or components. Although Paleo-Indian sites are found in approximately 60 percent of the planning area, they are most common in the Rio Chama Section.

Archaic Period (5500 B.C. to A.D. 400)

Consonant with a subsistence shift in the planning area is the appearance of new classes of artifacts, notably ground stone implements used to process plant foods for consumption, and projectile points appropriate for hunting smaller animals. There are an estimated 650 sites with Archaic occupations in the planning area, constituting approximately 8 percent of the total number of identifiable components in that area. Archaic sites are most prevalent in the Northern and Rio Chama Sections, but are found in all project reaches.

In the Northern Section, records obtained from the Colorado Historical Society, Office of Archaeology and Historic Preservation, indicate that 481 sites are situated within a 5-km buffer adjacent to Reaches 1 and 2. Reach 1 contains 127 recorded sites; Reach 2, which encompasses the margins of the Rio Grande mainstem, contains 354 known sites. The majority of sites in Reaches 1 and 2 are of unknown affiliation and time period. However, of those that can be assigned to specific time periods, most date to the middle to late Archaic period.

In northern New Mexico, including the project area, Archaic sites are best known from the Navajo Reservoir region southward to Gallegos Mesa, the Española basin, the Rio Santa Cruz basin, the Galisteo basin, the Chuska Valley, the Chaco region, and Arroyo Cuervo (Scheick 1996). In the southern New Mexico portion of the project area, Archaic sites are generally situated along the East and West Mesas adjacent to Las Cruces and parallel to the Rio Grande (Ackerly 1999; Camilli et al. 1988; Marshall and Walt 1984; Lekson 1999; Ravesloot 1988; Seaman et al. 1988).

Formative Period (A.D. 500 to A.D. 1492)

The appearance of the "Chaco phenomenon," a sequence of development centered in the Chaco Canyon region, had profound effects, primarily in the northern part of the project area. The Chaco locations were marked by large towns, housing complexes, and kivas.

The northern New Mexico portion of the planning area contains remains typically referred to as "Anasazi." Archaeological sites affiliated with Anasazi occupations are common in the Rio Chama Section (Schaafsma 1976; Whitten and Powers 1980), the Central Section along the main stem of the Rio Grande into the Cochiti Reservoir area (Biella and Chapman 1977), and southward into the Albuquerque region (Schutt and Chapman 1992). The sequence of prehistoric development in this area progresses through Basketmaker and Puebloan occupations from A.D. 200 to A.D. 1540.

The San Acacia and Southern Sections (Reaches 14-17) center on the Mogollon area of southern New Mexico, where a shift from nomadic hunting and gathering occurred about 2,000 years ago, reflected in progressively greater emphasis on the cultivation of crops prompted by increasing population growth. The subsequent Formative period is subdivided into Mesilla, Doña Ana, and El Paso phases, culminating in above-ground adobe pueblos, ceramics, some documented crops, tools, and more extensive regional interaction.

3.6.1.4 Historic Periods

The northern portion of the project area remained occupied from the arrival in 1598 of Spanish explorers through the Colonial, Mexican, and Euro-Anglo periods. In contrast, much of the southern project area was not occupied until the close of the Mexican Period, and settlements did not really expand until the arrival of Euro-Anglo settlers after 1848.

Spanish Period (A.D. 1540 to 1821)

Following earlier explorations by Coronado and other Spaniards, in 1598 Oñate established the first permanent settlement, San Gabriel village, near the present-day Pueblo of San Juan (Hammond and Rey 1938). Navajo elements were also identified in the Rio Chama basin upstream of Santa Clara Pueblo at this time (Schaafsma 2002). Many other pueblos were already established on major tributaries of the Rio Grande.

Extensive descriptions of the project area are included in the 1630 narrative of Benavides (Ayer 1965), as described in Appendix O, the Cultural Resources Appendix. By 1643, the overall number of pueblos in the project area had declined from 93 at the time of contact to only 38 (Barrett 2002) due to losses of land and the encomienda system with its forced labor. By the 1670s, the pace of pueblo abandonment had accelerated. Most Spanish settlements were concentrated along the Rio Grande corridor, while many outlying towns were abandoned because of raiding.

After the Pueblo Revolt of 1680, the 1,600-mile Camino Real de Tierra Adentro connected Mexico City with the far-flung colonies in New Mexico. Supply trains traveled back and forth between Santa Fe and Mexico City every 18 months. Although portions of its precise location remains uncertain, the Camino Real parallels the Rio Grande through the entire project area and has recently been designated a National Historic Trail.

In the 18^{th} century, sheep production became important for furnishing meat for the Spanish mines in northern Mexico and as a medium of exchange throughout much of New Mexico. The Old Spanish Trail was also established in the 18^{th} century, and, by the early 19^{th} century had become one of the major trading routes connecting New Mexico with Spanish settlements in Arizona area (Swadesh 1974).

Mexican Period (A.D. 1821 to 1848)

Mexico’s declaration of independence from Spain in 1821 was accompanied by the opening of the Santa Fe Trail. This period is also characterized by additional Mexican land grants and other settlements along the Central Section and to the east of Santa Fe. There was progressively greater interaction among American Euro-Anglos and New Mexico’s Native American and Hispanic residents. In recognition of increased trade with Americans from the east, Taos (in the Northern Section) was made an official port of trade in 1837.

The Mexican Period in the southern portions of the project area were typified by establishment of a number of new land grants (Bowden 1971; Williams 1986). These included, in chronological order, Santa Teresa (1790), Canutillo (1824), Bracito (alt. Brazito, 1824), Doña Ana Bend Colony Grant (1844), Refugio Colony Grant (1850), Mesilla Civil Colony Grant (1852), José Manuel Sanchez Baca Grant (1853), and the Santo Tómas de Yturbide Grant (1853). The almost immediate acquisition of this region by the U.S. under the Treaty of Guadalupe-Hidalgo (1848) and subsequent Gadsden Purchase(1854) resulted in the Mexican Period in this part of the project area having little impact.

In the San Acacia and Southern Sections, in the area between the Rio Puerco and El Paso, the early history is somewhat different from that observed in the Northern and Rio Chama Sections. Spanish and Mexican Period occupations are virtually absent, and most archaeological remains are associated with the Euro-Anglo Period. In that period, conditions between New Mexican statehood and the Civil War remained largely unchanged, with the few Hispanic settlements concentrated primarily in the Mesilla

Valley and sparse Anglo settlements largely centered in existing towns and villages. Settlement in the El Paso area did not expand greatly until the Apaches were subjugated by the U.S. in 1881.

Euro-Anglo Period (1848 to Present)

In 1846, Doniphan's California Column entered New Mexico, ushering in a new era in the region's history. With the subsequent defeat of the Mexican Army, New Mexico officially became a territory of the U.S.

Conditions during the period between 1848 and the outbreak of the Civil War (1860) remained largely unchanged from those observed during the Mexican Period. Hispanic settlements were very few in number and still concentrated mostly in the Mesilla Valley, while Anglos settled largely in existing towns and villages.

The planning area was impacted by the Civil War, during which Confederate forces seized Union posts beginning in El Paso and extending northward up the Rio Grande toward Santa Fe. Order returned to the area only after the Confederates were defeated at the Battle of Glorieta Pass in l862 (east of Santa Fe, New Mexico) and the Homestead Act was passed in that same year, facilitating Anglo settlement. From 1848 to 1880, virtually all of the Rio Grande floodplain between modern-day Las Cruces, New Mexico, and El Paso, Texas, had been claimed by the U.S.

After passage of the Homestead Act of 1862, the Reclamation Act of 1902 supported settlement by inaugurating large-scale water projects—notably Elephant Butte Dam—to stabilize water supplies to the newly arrived homesteaders.

In the mid- to late l9th century, farming and ranching constituted the major economic activity in the area and focused on sheep, although cattle became increasingly important. Development in the southern reaches of the Rio Grande basin began during the latter l9th century. Among the most important factors affecting development in the region was (1) resolution of water disputes between the U.S. and Mexico and (2) the appearance of large-scale irrigation and flood control projects under the auspices of the Bureau of Reclamation and the Corps.

Many initial economic activities typical of the mid-late l9th century focused on farming and ranching. Farming varied from rainfall-based dryland farming in upland areas to irrigated agriculture in river valleys that had relatively permanent flows. The establishment of settlements were frequently accompanied by the immediate construction of irrigation ditches (Ackerly 2002).

3.7 Agriculture

Within the upper Rio Grande basin, most of the agricultural acreage falls within a 5-km buffer on either side of two major rivers, the Rio Grande and Rio Chama. Approximately 7 percent of this buffer is devoted to agriculture (USGS and EPA 2000). The distribution of agricultural acreage by section is shown in **Figure 3-16**. Agricultural acreage includes irrigated and nonirrigated land, field crops, planted and native grass pastures, orchards, vineyards, and fallow fields in rotation. Irrigation is accomplished by using either surface water directed from the rivers or groundwater pumped up from wells. More detailed information concerning agriculture is contained in Appendix P-1.

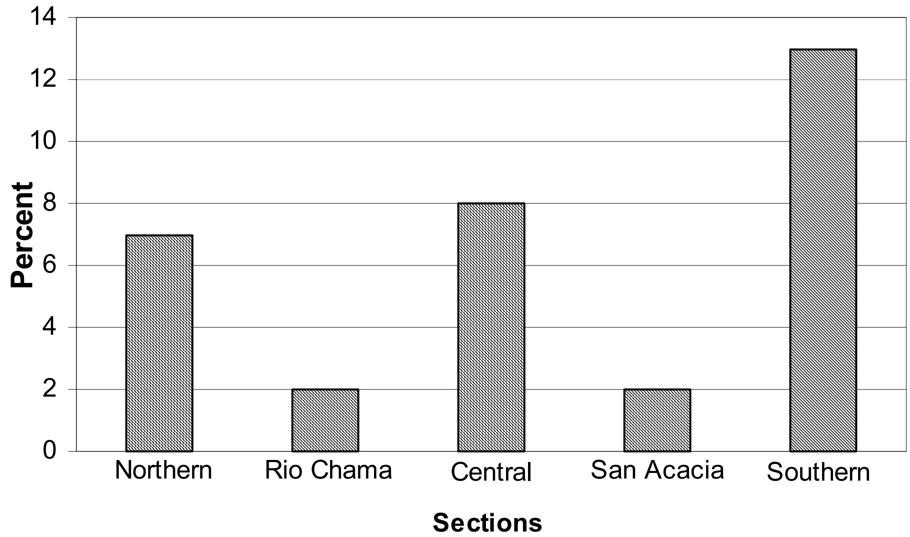


Figure 3-16. Percentage of Total Acreage of Agricultural Land along Each River Section

Source: USGS and EPA 2000

3.7.1 Irrigated Agriculture

Surface water is diverted along the Rio Chama and Rio Grande providing water for agriculture. Diverted water is distributed through ditches and acequia directly to growers. Several entities have authority and responsibility for distributing water and maintaining the diversion structures and channels that carry the water. New Mexico has over 800 acequia associations, ranging from small to large, mostly in the north part of the state (NMOSE 1998). The MRGCD is the main irrigation district/purveyor for growers between Cochiti and Elephant Butte Reservoirs. In addition, pueblos, private irrigators, and other users (such as the Bosque del apache), also divert water. The Elephant Butte and El Paso Irrigation Districts serve most growers in the Southern Section.

3.7.1.1 Northern Section

Most of the acreage in the Colorado portion of this section is devoted to pastures of native grasses grown for forage, with some acreage planted in alfalfa, small grains, and potatoes. In the New Mexico portion of this section, about 70 percent of the agricultural land is devoted to forage (irrigated pasture); about 6 percent is divided between small grains and fruits and vegetables (**Figure 3-17**). The rest (23 percent) is left fallow or used as rangeland (Lansford et al. 1993a, b, 1996).

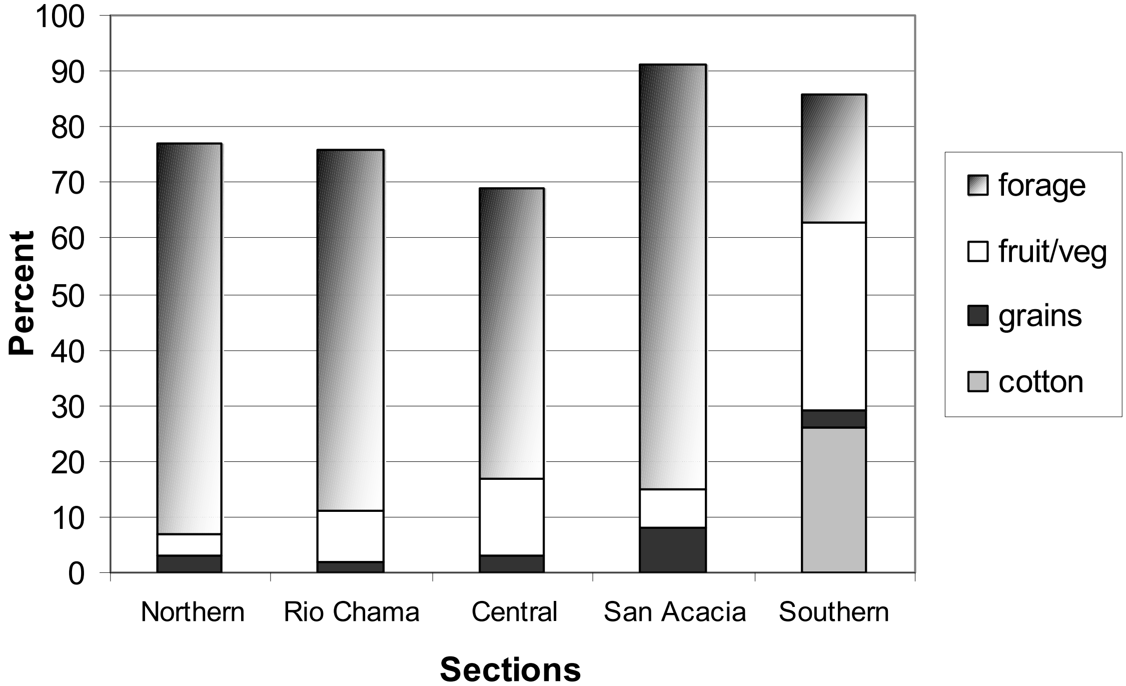


Figure 3-17. Percentage of Crop Type by River Section in New Mexico and Texas

Notes: Totals do not equal 100% because fallow pastures and rangeland were excluded.
Data are averaged from 1991 through 1995.
Crop types are categorized as follows:
Grains—wheat, barley, sorghum grown for grain, unspecified small grains
Forage—alfalfa, other hays, planted pasture, native pasture (all irrigated)
Fruits / vegetables—vegetables, vineyards, melons, peanuts, orchard fruits/nuts
Source: Derived from Lansford et al. 1993a, b, 1996.

3.7.1.2 Rio Chama Section

The percentages of crop types in the Rio Chama Section are similar to those in the Northern Section (Figure 3-17). Approximately 65 percent of the agricultural lands are devoted to forage (predominantly alfalfa); about 11 percent divided between small grains and fruits and vegetables. The rest (about 24 percent) is left fallow or used as rangeland. Water is diverted to several community acequia systems and tribal lands, including San Juan, Santa Clara, Pojoaque, and San Ildefonso Pueblos.

3.7.1.3 Central Section

The Central Section includes a number of tribal lands (Cochiti, San Felipe, Santa Ana, Santa Domingo, Zia, Sandia, and Isleta Pueblos), as well as the cities of Albuquerque, Belen, and Socorro, which may account for the somewhat higher level of agricultural land use. The MRGCD is the primary irrigation entity for growers along this section. In general, from the Northern to the Central Section, there is a decrease in land devoted to pasture forage and an increase in land planted in crops (Figure 3-17). Approximately 52 percent of the irrigated farmland is devoted to forage; about 17 percent is planted in grains, fruits and vegetables. The rest (about 31 percent) is left fallow or used as rangeland.

3.7.1.4 San Acacia Section

The San Acacia Section of the river flows near the La Joya Waterfowl Management Area, the Sevilleta and Bosque del Apache NWR, and Elephant Butte State Park, which may account for the somewhat lower levels of agricultural land use in this section. Overall, there is an increase in acreage devoted to pasture and a decrease in the amount of acreage left fallow. Approximately 76 percent of the agricultural acreage is devoted to forage; about 15 percent is planted in small grains, fruits and vegetables (Figure 3-17). Only about 9 percent is left fallow or used as rangeland.

3.7.1.5 Southern Section

The highest level of agricultural land use occurs in the Southern Section. Overall, fallow land decreases and land devoted to field crops and orchards increases in the Southern Section (Figure 3-17). Acreage devoted to forage decreases to a low of 23 percent, about the same amount as is planted in cotton (26 percent). Land planted in nuts, fruits, and vegetables represents about 15 percent of the total agricultural acreage. Fallow land and rangeland represent approximately 15 percent of the agricultural acreage.

3.7.2 Irrigation Water Source

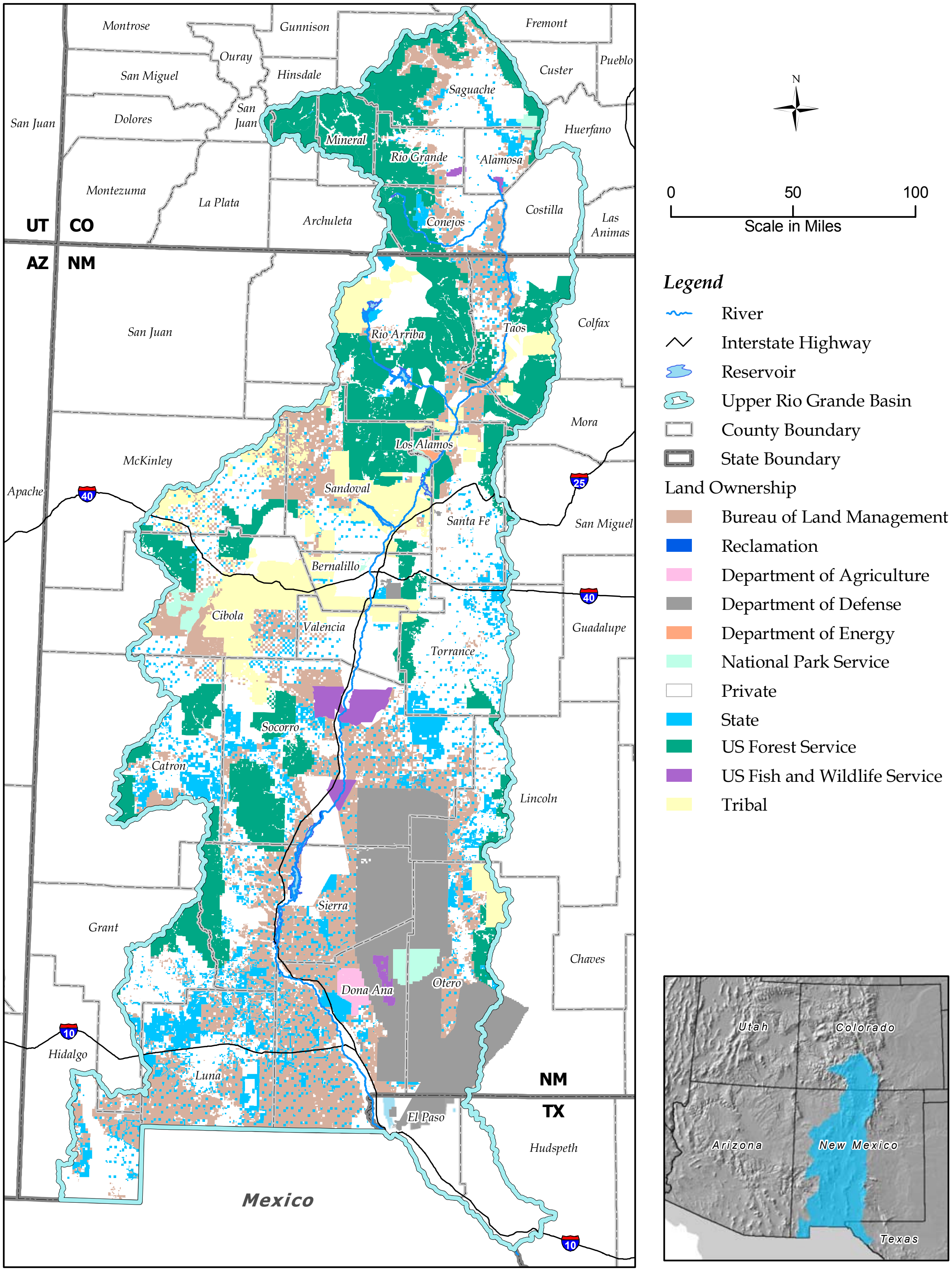
Most water used for agricultural irrigation in the Colorado portion of the Northern Section is diverted from surface water delivered from the Rio Grande and Rio Conejos by irrigation ditches or acequias (Vandiver 2003). Similarly, in the New Mexico portion of the Northern Section and in the Rio Chama Section, most irrigation of agricultural lands is accomplished by diverting surface water from the Rio Grande, Rio Chama, or their tributaries. In the Central Section, some of the irrigation involves a combination of diverted river water and groundwater pumped from private wells. The lands that use a combination of water sources tend to use the wells only in years when the surface water supply is insufficient. In the San Acacia and Southern Sections, lands are also irrigated using a combination of surface and groundwater (Landsford 1993a, b, 1996).

3.8 Land Use

Much of the land in the project area is undeveloped and natural. However, about 12 percent has been modified for a range of purposes including residential, commercial, industrial, transportation, communications and utilities, agricultural, institutional, and recreational uses. The attributes of land use addressed in this section include land status (ownership), general land use patterns and activities, land use management and specially protected areas on public, private, and tribal areas, and future land use trends. More detailed information concerning land use is contained in Appendix P-2.

3.8.1 Land Status (Ownership)

The upper Rio Grande basin encompasses over 36 million acres of land. The majority (83 percent) falls within the State of New Mexico; 13 percent falls within Colorado; and 4 percent within Texas. Ownership of these lands is a mixture of federal, state, tribal, and private. In a 2.8-million acre area within 5 km of the main river channel, almost 50 percent of the land is privately owned; about 36 percent is federally owned; and about 10 percent is sovereign land held by tribes and pueblos (NAUS, USGS, and ESRI 2003; GDT & ESRI 2003; BLM 2004). Only about 4 percent of the land is state owned. Land in the Northern Section, encompassing the more mountainous watersheds of the river, is predominantly federally owned. Sovereign lands are concentrated in the lower Rio Chama and Central Sections. Below these areas, the proportion of private land increases in New Mexico. In Texas, the land is almost entirely privately owned. **Map 3-7** shows the general land ownership for the upper Rio Grande basin.



1 **Map 3-7. Land Ownership in Rio Grande Basin**

3.8.2 Generalized Land Use

3.8.2.1 Land Management and Special Areas

Public Lands

Federal land is primarily managed by the BLM and the U.S. Forest Service (FS). The land within 5 km of the river encompasses four national forests and five BLM administrative offices (BLM 2004; GDT and ESRI 2003). Both agencies manage public land primarily for multiple uses according to land and resource management plans under the authority of existing laws. Forestry, grazing, and recreation are common activities on FS land; grazing, mineral development, and recreation are common activities on BLM lands. New Mexico state lands are held in trust to benefit public schools and other public institutions from the revenues they generate (in taxes, royalties, permit fees) and have a similar range of productive uses.

Some areas are designated or delineated for special use or protection, such as parks and monuments, wilderness areas, wildlife refuges, and wild and scenic river corridors. There are 14 national and state parks and monuments within 5 km of the river (GDT and ESRI 2003). Two national monuments (Bandelier and Chamizal) are close to the river. Most reservoirs are associated with a state park. Areas with a recreation emphasis are described in more detail in the River and Reservoir Recreation section.

There are several national and state wildlife refuges each with specific guidelines for protecting wildlife. Their functioning is dependent on the riparian environment and on water deliveries from the river. The most prominent among the wildlife areas, occurring in the San Acacia Section, is the Bosque del Apache NWR established in 1939. Its main purpose is to serve as a refuge and breeding grounds for migratory birds.

Over 60 miles of the Rio Grande in the Northern Section and 6 miles of the Rio Chama have the Wild and Scenic River (W&SR) designation (BLM 2000). The Rio Grande W&SR is jointly managed by BLM and the Carson National Forest. Maintaining the visual and natural qualities of these areas is a high priority. The Northern and Rio Chama Sections offer exceptional recreational opportunities for rafting and kayaking and limited camping along the river. In Colorado, 41 miles of the Rio Grande are under interim protection pending W&SR designation.

The planning area also includes several wilderness areas, managed for their pristine and natural qualities. Wilderness areas in the planning area include:

- South San Juan Wilderness located at the headwaters of the Rio Grande in Colorado;
- Rio Chama Wilderness, which straddles the Rio Chama below El Vado Lake;
- Dome and Bandelier Wilderness areas, which are just north of Cochiti Reservoir and link the Bandelier National Monument to the river through hiking trails;
- Bosque del Apache Wilderness, an extension of the NWR in the San Acacia Section.

Private Lands

Counties may exert control over use of privately held lands, although few counties have controls in effect that are based on land use, such as zoning ordinances. Most counties limit development within Federal Emergency Management Agency floodplains by not issuing building permits for structures within designated floodplains. Despite controls, development occurs in floodplains in some areas and is at risk from water operations, particularly during high flows. Privately owned reservoir shoreline occurs at Abiquiu Lake, where owners have built private boat docks and ramps to access the lake (Corps 2002).

Major urban areas (e.g., Santa Fe, Albuquerque, Rio Rancho, Las Cruces, and El Paso) as well as smaller municipalities (e.g., Taos, Española, Bernalillo, Belen, Socorro, and Truth or Consequences) include river floodplains within their corporate boundaries. Development of floodplains within each municipality is guided by comprehensive plans and controlled through zoning ordinances and subdivision regulations.

These determine the type and extent of land use allowable in specific areas and are intended to promote the use of land for the benefit of public health, welfare, and safety.

Rights-of-Way and Easements

Easements and rights-of-way allow certain entities to use or access land along the river and reservoirs for specific purposes (Horner 2004). Flowage easements exist around some reservoirs. Land in the easements may be flooded when the need exists for flood management. In some cases, encroachment into easement lands is occurring. For example, at Abiquiu Lake, private owners have built structures in easements that may be flooded (Dunlap 2001). Along the river, irrigation districts and acequias have rights-of-way to perform duties associated with distribution of water to growers and to maintain equipment, ditches and diversion structures (Horner 2004).

Pueblo and Tribal Lands

Pueblos and tribes control and manage sovereign lands and infrastructure along the river (Map 3-6). The planning area includes almost 2.6 million acres of sovereign lands. The 5-km buffer along the river includes about 320,000 acres of sovereign land, including 16 pueblo and tribal entities. Sovereign land accounts for a substantial portion of land immediately adjacent to the river in the Rio Chama and Central Sections. Deliveries of surface water are made to pueblos and tribes for municipal, industrial, agricultural, recreation, and various customary uses. Pueblos and tribes manage their lands according to their own policies and purposes, including fishing and boating.

3.8.3 Future Land Use Trends

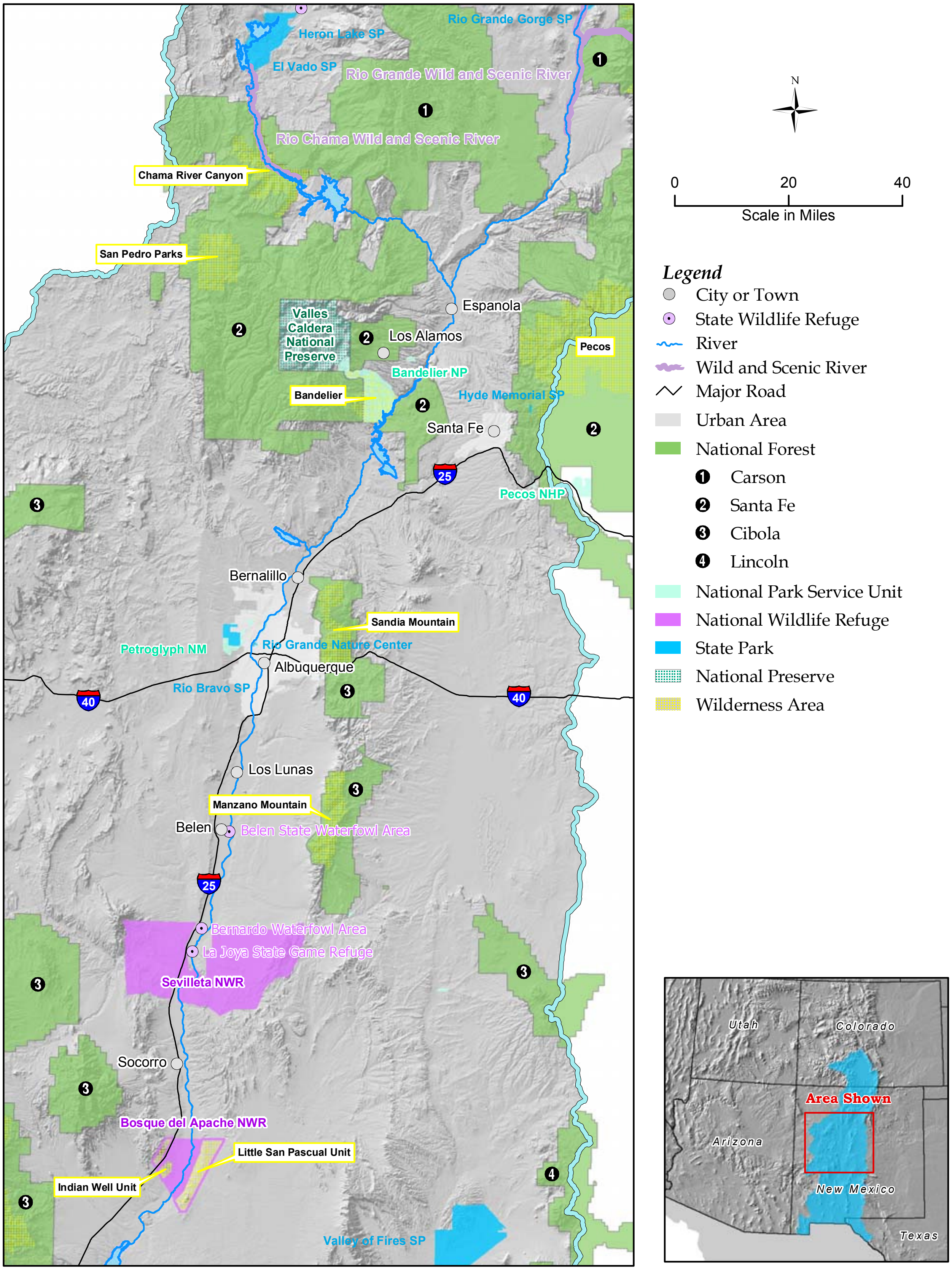
Regional and local planning initiatives are underway. These initiatives focus on issues related to future growth and development, such as land use, transportation, and water resources planning, that are built on future population projections. Development contributes to runoff that may enter the river system. The area of greatest projected land use change along the river is in the Central Section. Both the USGS and the Mid-Region Council of Governments studied changes in land use and developed a future land use framework based on trends and certain assumptions for projected growth in this area (USGS 2000b; MRCOG 2002). The URGWOM planning model did not consider population growth or land use changes over the 40-year period. Additional information on the URGWOM planning model is provided in Appendix I.

3.9 Recreation

In the dry west, where surface water is limited and variable from year to year, riverine water provides unique opportunities for recreation. Reservoir recreation occurs as a byproduct of dams built to store irrigation waters and to control floodwaters and sedimentation. Due to congressional action, certain reservoirs along the Rio Grande also serve wildlife enhancement purposes. More detailed information is contained in Appendix P-5. **Map 3-8** shows the location of public recreational lands along the river corridor.

3.9.1 River Recreation Sites and Activities

Within 5 km of the river, about 36 percent of the land is federally- or state-owned and generally open to the public. Dispersed recreation is enjoyed on these public lands. The Rio Chama and Rio Grande flow through or are adjacent to five National Forests; five Wilderness Areas; six wildlife areas; two W&SR sections; and several national and state parks, monuments, and developed recreation sites that provide a variety of recreational opportunity. The primary recreational activities along the river are rafting and fishing, while dispersed recreation activities, such as camping, walking, biking, hiking, wildlife viewing, and picnicking, are also popular.



Map 3-8. Recreation Areas within the River Corridor

Fishing is one of the primary recreational opportunities along the Rio Grande and its tributaries. The NMDGF recorded a total of almost 3.7 million angler-days during 1998/1999, of which about 25 percent was along the mainstem in the project area (derived from NMDGF 2000). Popular fish include river trout, bass, Kokanee salmon, lake trout, walleye, and pike. The trend over the last decade shows a general increase in fishing (Hansen 2003a).

Northern and Rio Chama Sections

In the Northern and Rio Chama Sections, kayaking, rafting, fishing, and wildlife viewing are the predominant recreational activities on the river. Recreation sites include the Wild River and Orilla Verde Recreation Areas in the Northern Section; and the area below El Vado Dam and El Vado State Wildlife and Fishing area in the Rio Chama Section (Hansen 2003b; BLM 2000).

High quality river rafting and kayaking provide the bulk of river recreation in the Northern and Rio Chama Sections. Rafting occurs during the spring and summer when there are sufficient flows. About 50,000 people float the Rio Grande annually in the Northern Section. About 5,000 people per year float the Rio Chama. Portions of the river have special designations to protect their primitive, wild, and scenic qualities (BLM 2000). Drought conditions and fire risk in the surrounding forests can seriously affect rafting opportunities and rafter numbers from year to year.

The Northern and Rio Chama Sections offer coldwater fishing. Popular fishing locations along the Rio Grande in these sections occur above and below Pilar. On the Rio Chama, fishing is popular below El Vado and Abiquiu Dams. Local flow rates are important to the quality of fishing conditions (Hansen 2003a).

Central Section

In the Central Section, recreation along the river includes activities such as boating, biking, hiking, and wildlife viewing along the river. Key access points include Coronado State Park, the Rio Grande Valley State Park, and Valley Nature Center. Hiking, walking, biking, and nature wildlife viewing are popular on MRGCD lands.

Popular fishing locations occur at Tingley Aquatic Park in Albuquerque; along the Albuquerque and Corrales irrigation ditches and drains; and along the Belen and Peralta drains. High flows out of Cochiti tend to improve conditions for fishing (Hansen 2003b).

San Acacia and Southern Sections

Flow rates in the San Acacia and Southern Sections are generally lower than in the Northern and Rio Chama Sections and do not support extensive instream recreation. Wildlife viewing, particularly birding, is enjoyed all along the river due to the high diversity of habitats. The San Acacia and Southern Sections both offer warmwater fishing.

In the San Acacia Section, wildlife viewing is popular at Bosque del Apache NWR. The river flows through or adjacent to four national wildlife refuges and three state refuges, all of which feature migratory birds and water fowl. The most notable of these is the Bosque del Apache NWR and Wilderness Area in the San Acacia Section, renowned for its sandhill crane population. Over the past five years, about 150,000 people have visited the refuge annually (FWS 2004).

3.9.2 Reservoir Recreation Sites and Activities

The project area includes eight reservoirs with recreational uses that include sightseeing, camping, picnicking, hiking, wildlife viewing, biking, hunting, fishing, swimming, boating and winter sports. Visitation to reservoir facilities has declined over the last several years, with a similar trend observed for all parks and monuments in the state (NMEMNRD 2001, 2002). Fishing is popular at reservoirs, both from the shore and from boats. Angler days exceeded 1 million at reservoirs in the project area in the 1998/1999 fishing cycle (NMDGF 2000), but declined to about 660,000 in 2000/2001 (Hansen 2003a).

This decrease corresponds to the overall trend of declining visitation to state parks in general and reservoirs in particular throughout New Mexico.

Northern and Rio Chama Sections

Reservoirs in the Northern and Rio Chama Sections (Heron/El Vado, Abiquiu and Cochiti) generally experience relatively low use; combined, they account for only about 26 percent of the 2.7 million reservoir visits in 2000 (**Figure 3-18**). Distance from concentrated populations, lower water levels and boating restrictions may account for visitation preference. For example, Heron Lake allows no powered boats, but provides for a quieter experience for camping, fishing, swimming, and sailing. Trout and salmon are the primary sport fish at coldwater reservoirs (Heron, Abiquiu, El Vado, Platoro). Cochiti Reservoir is primarily a warmwater fishery.

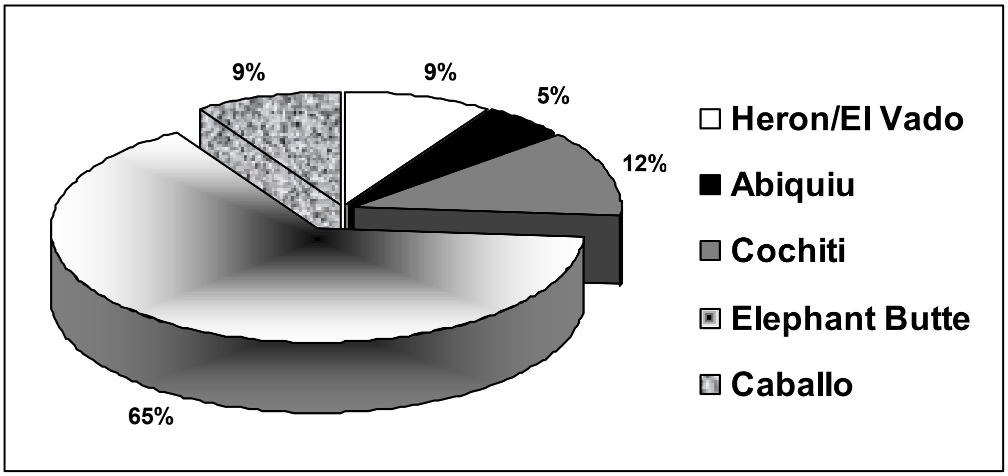


Figure 3-18. Reservoir Visitation in Project Area (2000)

Note: No data available for Platoro Reservoir. Jemez Canyon is a dry dam without recreational facilities and is not included.
Source: Casados 2001; NMEMNRD 2001, 2002

Southern Section

In the Southern Section, Elephant Butte State Park, Caballo State Park, Leasburg Dam State Park, and Percha Dam State Park are all popular recreation sites, along with several historic parks and the Feather Lake Wildlife Sanctuary in Texas. Both Elephant Butte and Caballo serve New Mexico residents and out-of-state visitors from El Paso and beyond.

Elephant Butte Reservoir received 65 percent and Caballo Reservoir received 9 percent of total visits to reservoirs in the project area in 2000 (Figure 3-18). Both locations allow use of motorized watercraft. Commercial marina facilities are operated at Elephant Butte. In New Mexico, all state parks combined receive between 4 and 5 million visitors, annually. Almost 40 percent of these visits are to Elephant Butte State Park and Reservoir. Warm water at Elephant Butte and Caballo Reservoirs support crappie, bass, and catfish sport fishing.

3.10 Flood Control

Along the Rio Grande and its tributaries, there are many flood control structures, from dams to levees. There have been no property damages sustained nor anticipated from direct releases by the flood control facilities under consideration in this EIS. However, residual flood damages could occur from unregulated drainages depending on flows. Evaluation of alternatives, therefore, focuses on changes in residual flood damages associated with the proposed operation changes. The affected environment includes both the current flood control structures and benefits as well as the areas that remain threatened by floods.

3.10.1 Relevant Affected Geographic Area and Historical Flooding

Major floods occurred in the 1940s. However, since the inception of total flood control by the Corps along the Rio Grande and its tributaries, benefits have totaled more than $1.1 billion (Corps 2003). In addition, significant damages have been prevented in terms of river sedimentation. Historically, however, the Northern and Southern Sections, the primary areas that have sustained damages as a result of flooding from the Rio Grande since 1979, are not influenced by operations at any of the facilities under consideration in this EIS. Historical flooding since 1979 in the Northern and Southern Sections is discussed in Appendix P-3.

3.10.1.1 Northern Section

Some agricultural damages and some minor damages to structures were sustained in areas of Colorado (Del Norte, Monte Vista, and Alamosa). There were no Corps flood control projects in these areas at the time of the damage, although a levee system for Alamosa was recently completed.

In New Mexico, damages occurred along the Rio Grande from Pilar to the confluence of the Rio Chama during several high runoff years since 1979. Damage has occurred primarily to bridges, diversion structures, pastures, orchards, and low-lying agricultural areas.

3.10.1.2 Rio Chama Section

Abiquiu Dam has provided over $391.5 million in cumulative flood control benefits since its construction (Corps 2003). Minor bank erosion damages were periodically sustained between Abiquiu Dam and Cochiti Lake along the Rio Chama and the Rio Grande.

3.10.1.3 Central and San Acacia Sections

Cochiti Dam has provided over $435.5 million in cumulative flood control benefits since it was constructed (Corps 2003). No flood damages have been reported in these sections since 1979. However, as a result of nonengineered levees or other factors such as large uncontrolled drainage areas, these sections may be prone to flooding and are currently under study by the Corps.

3.10.1.4 Southern Section

Major damages were sustained in Mexico in 1986 and 1987 as a result of 14 levee breaks in the Southern Section in the U.S. resulting from high flows on the Rio Grande. Structures as well as a significant amount of agricultural land were destroyed or damaged.

High flows in the Rio Grande in El Paso County, Texas, in 1986 caused damage to pecan orchards and to the diversion structure of the El Paso Irrigation District. The pecan orchards were primarily damaged from the high ground water table resulting from the Rio Grande flows. The Riverside Diversion, which brings water into the El Paso Irrigation District from the Rio Grande, was permanently damaged from high river flows. The regulating gates are currently inoperable and locked in the closed position. The structure is functioning to divert water, but is unable to sluice sediment. A rock berm with a concrete cap was placed at the downstream toe of the diversion to prevent complete failure of the structure.

Damages occurred in Hudspeth County, Texas, where high releases from Elephant Butte in 1986 and 1987 caused damage primarily to agricultural lands. The total damages estimated from the 1986 Elephant Butte Reservoir releases include more than $1 million to clean up sediment; more than $200,000 in pump purchases and operation to prevent the Hudspeth County Irrigation drainage ditches from overflowing; $220,000 in lost yields and production (compensable by the Agricultural Stabilization and Conservation Services); and an immeasurable impact on future yields due to increased salinity.

High reservoir levels at Elephant Butte increased the amount of sedimentation at the head of the reservoir, creating a risk of river flows overtopping the levee and flooding the low flow conveyance channel.

Historically, damages occurred on many of the tributaries to the Rio Grande (e.g. Hatch, New Mexico and parts of Socorro County). However, consideration of damages in the Southern Section are not explicitly analyzed in this Review and EIS because proposed changes to operating plans would not affect these areas.

3.11 Hydropower

Hydropower production is affected by storage regulation and allocation at various reservoirs in the upper Rio Grande basin. These areas are at the El Vado Reservoir, Abiquiu Reservoir, and Elephant Butte Reservoir. The first two are located on the Rio Chama, and the latter is on the Rio Grande near the city of Truth or Consequences in the Southern Section. Power is generated by "run of the river" facilities at El Vado and Abiquiu. In other words, power generation occurs incidentally with flow releases from these dams. Elephant Butte power production depends on scheduled block releases and demand for power. Changes in operation will affect the total generation from these plants. More detailed information concerning the hydropower facilities along the Rio Grande is contained in Appendix P-3. **Figure 3-19** shows the output of the hydropower plants at El Vado, Abiquiu, and Elephant Butte in thousands of megawatt hours.

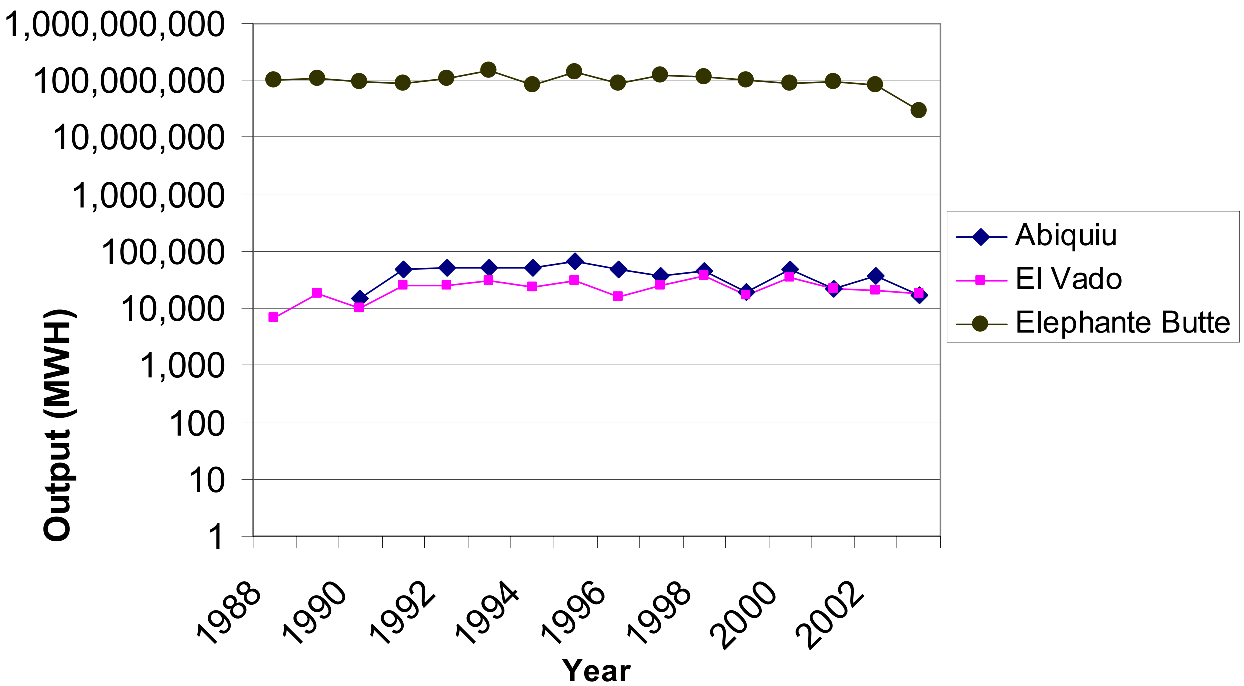


Figure 3-19. Historic Hydropower Generation

Sources: Treers 2004; Biggs 2004

3.12 Socioeconomics

The region of influence for socioeconomics includes 14 counties adjacent to the Rio Grande, Conejos River, and the Rio Chama, and two additional counties linked through economic and social ties. There are two major urban centers located in the three-state planning area: Albuquerque, New Mexico and El Paso, Texas. Together these two cities account for about 73 percent of the total planning area population. There are smaller municipalities located throughout the planning area that make important contributions to the regional economy. Agriculture, recreation, tourism, and manufacturing are important sectors in the regional economy. More detailed information concerning socioeconomics is contained in Appendix P-6.

3.12.1 Demographics

According to the 2000 Census, there were nearly 1.7 million people in the three-state project area above El Paso. About 18,900 of that 1.7 million live in the Colorado portion of the planning area. Approximately 50 percent of these Colorado residents are of Hispanic origin; only about 2.5 percent are of Indian ancestry; the remainder are African American or white (Census 2000a).

Almost 1 million people were located in the New Mexico portion of the project area according to the 2000 Census. Of these residents, nearly 50 to 75 percent are of Hispanic origin; about 5.6 percent are of Indian origin; the remainder is largely white or African American (Census 2000b). Of the 681,100 residents of the Texas portion of the project area, about 75 percent are of Hispanic origin; only about 1 percent is of Indian origin; the remainder is white or African American (Census 2000c).

New Mexico population projections were developed for the recently approved New Mexico State Water Plan (NMISC 2003) to support regional water planning efforts. The State of Colorado Division of Local Government has generated official population projections by county and region for the years 2000 to 2030 (CDLG 2004). The Texas Office of the State Demographer has produced population estimates and projections to the year 2040 for Texas counties (Texas State Data Center 2004). **Table 3-9** summarizes projections and **Table 3-10** summarizes growth rates for the counties that contain segments of the Rio Grande and Rio Chama over the next 40 years (30 years for Colorado Counties).

Overall, the population in the New Mexico potion of the study region is projected to increase by almost 60 percent (from about 1 million in 2000 to about 1.6 million in 2040). The populations in Valencia and Santa Fe Counties may more than double over the next 40 years, whereas the northern areas will experience the slowest growth (BBER 2003). The population of El Paso County, Texas is projected to increase by 50 to 82 percent from 2000 to 2040, from about 680,000 people to 1.0 to 1.2 million people. Growth in the rural areas of the Texas portion of the study area is expected to be much lower, with Hudspeth County growing by 16 to 27 percent over the 40 year period. Growth in the Colorado portion of the study region is projected to grow by about 34 percent from 2000 to 2030. This growth is projected to be spread out fairly evenly throughout the five Colorado counties.

3.12.2 Economics

The retail trade sector accounts for the largest portion of sales and business receipts in most of the region of influence (University of Virginia Library 2004). The large impact from retail trade is in part due to the large amount of tourism in the area, which is reflected in the healthy accommodations/food service sector. Other sectors that consistently account for large percentages of sales and receipts in the project area include manufacturing, wholesale trade, health care and social services, and professional and technical services. Manufacturing and wholesale trade are particularly important in the counties that include larger cities, such as Bernalillo, Santa Fe, Sandoval, Doña Ana, and El Paso Counties.

3.12.2.1 Agriculture

Agriculture remains an important part of the area’s economy. In 1999, over 9,000 people were directly employed on farms within the region of influence. About 33 percent of the direct agricultural employment was in Colorado; 53 percent was in New Mexico, and the remaining 14 percent was in Texas.

Table 3-9. Projected County Population and Annual Average Growth Rate

2000 to 2040									
Counties/Key Municipalities	**Total County Population by Projection Year (5 year increments)**								
	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
Colorado Counties									
Alamosa	15,132	15,946	17,066	18,308	19,609	20,926	22,223	—	—
Conejos	8,402	8,538	8,840	9,215	9,530	9,799	10,020	—	—
Costilla	3,665	3,792	3,958	4,134	4,277	4,415	4,546	—	—
Rio Grande	12,432	13,061	13,633	14,315	14,922	15,409	15,729	—	—
Saguache	5,954	6,634	7,125	7,581	8,002	8,341	8,603	—	—
New Mexico Counties									
io Arriba	41,307	43,694	46,030	48,196	50,027	51,451	52,519	53,269	53,676
Los Alamos	18,359	18,722	19,122	19,122	20,099	20,565	20,866	21,034	21,224
Santa Fe	129,936	143,987	158,624	174,400	191,403	208,801	226,112	244,751	264,778
Bernalillo	558,437	593,801	623,421	650,497	675,818	699,267	720,635	739,734	756,525
Valencia	66,699	76,503	86,670	97,242	107,906	118,339	128,527	138,590	148,563
Socorro	18,165	19,824	21,472	23,102	24,673	26,139	27,527	28,846	30,086
Sandoval	89,668	106,928	124,058	141,662	159,162	176,177	192,745	208,797	224,259
Sierra	13,355	15,058	16,700	18,281	19,774	21,172	22,485	23,644	24,567
Doña Ana	175,524	197,472	218,788	238,677	256,254	272,764	289,897	306,907	322,568
Texas Counties									
El Paso (High)	679,622	748,258	824,786	904,596	981,274	1,051,853	1,118,871	1,181,836	1,237,030
El Paso (Low)	679,622	732,098	781,599	828,143	870,402	911,133	950,255	986,544	1,018,785
Hudspeth (High)	3,344	3,510	3,679	3,813	3,920	3,965	3,964	3,934	3,878
Hudspeth (Low)	3,344	3,646	3,919	4,098	4,255	4,331	4,350	4,317	4,239

Table 3-10. Projected Population Growth Rates

	Projected Growth Rate (%) of County Population by Projection Years							
	2000-05	2005-10	2010-15	2015-20	2020-25	2025-30	2030-35	2035-40
Colorado Counties								
Alamosa	1.10	1.40	1.40	1.40	1.30	1.20	—	—
Conejos	0.30	0.70	0.80	0.70	0.60	0.40	—	—
Costilla	0.70	0.90	0.90	0.70	0.60	0.60	—	—
Rio Grande	1.00	0.90	1.00	0.80	0.60	0.40	—	—
Saguache	2.20	1.40	1.20	1.10	0.80	0.60	—	—
New Mexico Counties								
Rio Arriba	1.12	1.04	0.92	0.75	0.56	0.41	0.28	0.15
Los Alamos	0.39	0.42	0.49	0.51	0.46	0.29	0.16	0.18
Santa Fe	2.05	1.94	1.90	1.86	1.74	1.59	1.58	1.57
Bernalillo	1.23	0.97	0.85	0.76	0.68	0.60	0.52	0.45
Valencia	2.74	2.50	2.30	2.08	1.85	1.65	1.51	1.39
Socorro	1.75	1.60	1.46	1.32	1.15	1.03	0.94	0.84
Sandoval	3.52	2.97	2.65	2.33	2.03	1.80	1.60	1.43
Sierra	2.40	2.07	1.81	1.57	1.37	1.20	1.01	0.77
Doña Ana	2.36	2.05	1.74	1.42	1.25	1.22	1.14	1.00
Texas Counties								
El Paso (High)	1.94	1.97	1.86	1.64	1.40	1.24	1.10	0.92
El Paso (Low)	1.50	1.32	1.16	1.00	0.92	0.84	0.75	0.64
Hudspeth (High)	1.74	1.45	0.90	0.75	0.35	0.09	-0.15	-0.36
Hudspeth (Low)	0.97	0.94	0.72	0.55	0.23	-0.01	-0.15	-0.29
Sources:								

Hay, wheat, and corn are the major crops grown in the Northern and Central Sections. Hay and chiles are grown in the San Acacia Section. Chiles, pecans, and cotton grown in the Southern Section provide significant farm income. Cattle ranching is also an important agricultural activity in the region. In 1999, within the region of influence, there were more than 200,000 head of cattle in New Mexico, about 100,000 head in Colorado, and about 64,000 head in Texas.

According to the 1997 Census of Agriculture (U.S. Department of Agriculture [USDA] 1998a, b, c), the total market value of agricultural products was $222 million in Colorado, $135 million in New Mexico, and $101 million in Texas. Total farm expenses were about $168 million in Colorado, $106 million in New Mexico, and $75.5 million in Texas.

3.12.2.2 Income and Employment

The Colorado and Texas portions of the 16-county region of influence generally have a lower income than the New Mexico portion. Per capita personal income data (all categories) show the same pattern, with the more urbanized New Mexico counties (Los Alamos, Bernalillo, and Santa Fe Counties) having higher incomes than the other portions of the planning area.

Median household income in most counties in the region of influence ranges from about $20,000 to $30,000 (Census 2000a, b, c). The most notable exception is the median household income of $78,993 in Los Alamos County in New Mexico, associated with Los Alamos National Laboratory. Median income, per capita income, and the percentage of the population below the poverty line within counties in the planning area and key municipalities are shown in **Table 3-11**.

Table 3-11. Comparison of Income Levels within the Planning Area to the Nation

Region	Median Household Income	Per Capita Income	Population Below Poverty
UNITED STATES	**$41,994**	**$21,587**	**12%**
COLORADO	**$47,203**	**$24,049**	**9%**
Alamosa County	**$29,447**	**$15,037**	**21%**
Alamosa	$25,453	$15,405	15%
Conejos County	**$24,744**	**$12,050**	**23%**
Costilla County	**$19,531**	**$10,748**	**27%**
Rio Grande County	**$31,836**	**$15,650**	**14%**
Monte Vista	$28,393	$13,612	15%
Saguache County	**$25,495**	**$13,121**	**23%**
NEW MEXICO	**$34,133**	**$17,261**	**18%**
Bernalillo County	**$38,788**	**$20,790**	**14%**
Albuquerque	$38,272	$20,884	14%
Tijeras	$34,167	$18,836	10%
Doña Ana County	**$29,808**	**$13,999**	**25%**
Hatch	$21,250	$14,619	34%
Las Cruces	$30,375	$15,704	23%
Mesilla	$42,275	$25,922	9%
Sunland Park	$20,164	$6,576	39%
Los Alamos County	**$78,993**	**$34,646**	**3%**
Los Alamos	$71,536	$34,240	4%
Rio Arriba County	**$29,429**	**$14,263**	**20%**
Chama	$30,513	$16,670	18%
Española	$27,144	$14,303	22%
Sandoval County	**$44,949**	**$19,174**	**12%**
Bernalillo	$30,864	$13,100	18%
Cuba	$21,538	$11,192	41%
Jemez Springs	$36,818	$19,522	21%
San Ysidro	$30,521	$14,787	15%
Rio Rancho	$47,169	$20,322	5%
Santa Fe County	**$42,207**	**$23,594**	**12%**

Region	Median Household Income	Per Capita Income	Population Below Poverty
Santa Fe	$40,392	$25,454	12%
Edgewood	$42,500	$18,146	11%
Sierra County	**$24,152**	**$15,023**	**21%**
Elephant Butte	$31,705	$21,345	11%
T or C	$20,986	$14,415	23%
Williamsburg	$23,750	$15,549	10%
Socorro County	**$23,439**	**$12,826**	**32%**
Magdalena	$22,917	$13,064	25%
Socorro	$22,530	$13,250	32%
Taos County	**$26,762**	**$16,103**	**21%**
Questa	$23,448	$13,303	24%
Red River	$31,667	$17,883	10%
Taos	$25,016	$15,983	23%
Valencia County	**$30,099**	**$14,747**	**17%**
Belen	$26,754	$12,999	25%
Los Lunas	$36,240	$14,992	14%
TEXAS	**$39,927**	**$19,617**	**15%**
El Paso County	**$31,051**	**$13,421**	**24%**
El Paso	$32,124	$14,388	22%
Fabens	$18,486	$6,647	43%
Hudspeth County	**$21,045**	**$9,549**	**36%**

Sources: Census 2000a,b,c

Unemployment in the region of influence averaged 5.4 percent in 2001. In New Mexico counties, the unemployment rate is 3.8 percent, compared to 7.1 percent for Colorado counties (CDOLE 2004), and 8.2 percent for Texas counties (State of Texas 2004). The unemployment rate for New Mexico counties is lower due to the below average rates in Los Alamos County (1.0 percent), Santa Fe County (2.6 percent), and Bernalillo County (3.5 percent) (New Mexico Department of Labor [NMDOL] 2004).

3.12.2.3 Recreation and Tourism

Recreation has a significant impact on the regional economy. Average recreation expenditures in New Mexico according to the 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation was about $46 per trip for fishing, $57 per trip for hunting, and $63 per trip for wildlife watching (FWS 2002b). Reservoir recreation-related spending alone could exceed $100 million annually (FWS 2002b). Dispersed and river recreation usage is not recorded by trips or visits and cannot be assigned an economic value.

3.13 Environmental Justice

As of February 11, 1994, Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, requires that each federal agency consider environmental justice as part of its mission. The Executive Order has the following three objectives:

- To focus the attention of federal agencies on human health and general environmental conditions in minority and low-income communities with the goal of achieving environmental justice;
- To foster nondiscrimination in federal programs that could substantially affect human health or the environment; and
- To give minority and low-income communities greater opportunities for public participation on matters relating to human health and safety.

Environmental justice addresses the issue of disproportionate impacts on minority and/or low-income populations. Therefore, the locations of these populations must be known in order to evaluate potential environmental justice issues. For this analysis, populations with a high percentage of people of Hispanic origin, a high percentage of Native Americans, and a high percentage of low-income households or high poverty rates are identified. The locations of these identified populations are used to evaluate Environmental Justice concerns.

The greatest proportions of populations of Hispanic origin or Native American people are in New Mexico. All of the states in the planning area are well above the average proportion of Hispanic population for the entire U.S. (13 percent). The most useful comparison for evaluating environmental justice concerns within the planning area is to consider the percentage in individual counties and municipalities to the states and nation, as shown in **Table 3-12**.

Table 3-12. Comparison of the Racial/Ethnic Populations in the Planning Area and Nation

Region	Total Population	White	Black	American Indian	Asian	Other Race	More Than One Race	Hispanic or Latino
UNITED STATES	**281,421,906**	**75%**	**12%**	**1%**	**4%**	**6%**	**2%**	**13%**
COLORADO	**4,301,261**	**83%**	**4%**	**1%**	**2%**	**7%**	**3%**	**17%**
Alamosa County	**14,966**	**71%**	**1%**	**2%**	**1%**	**21%**	**4%**	**41%**
Alamosa	7,960	69%	1%	2%	1%	23%	4%	47%
Conejos County	**8,400**	**73%**	**<1%**	**2%**	**<1%**	**22%**	**4%**	**59%**
Costilla County	**3,663**	**61%**	**1%**	**2%**	**1%**	**30%**	**5%**	**68%**
Rio Grande County	**12,413**	**74%**	**<1%**	**1%**	**<1%**	**22%**	**3%**	**42%**
Monte Vista	4,529	63%	<1%	2%	<1%	32%	3%	58%
Saguache County	**5,917**	**71%**	**<1%**	**2%**	**<1%**	**23%**	**3%**	**45%**
NEW MEXICO	**1,819,046**	**67%**	**2%**	**10%**	**1%**	**17%**	**4%**	**42%**
Bernalillo County	**556,678**	**71%**	**3%**	**4%**	**2%**	**16%**	**4%**	**42%**
Albuquerque	448,607	72%	3%	4%	2%	15%	4%	40%
Tijeras	474	66%	0%	1%	<1%	28%	5%	56%
Doña Ana County	**174,682**	**68%**	**2%**	**1%**	**1%**	**25%**	**4%**	**63%**

Region	Total Population	White	Black	American Indian	Asian	Other Race	More Than One Race	Hispanic or Latino
Hatch	1,673	46%	<1%	1%	0%	3%	50%	79%
Las Cruces	74,267	69%	2%	2%	1%	4%	22%	52%
Mesilla	2,180	74%	<1%	1%	<1%	4%	21%	52%
Sunland Park	13,309	70%	1%	1%	<1%	26%	3%	96%
Los Alamos County	**18,343**	**90%**	**<1%**	**1%**	**4%**	**3%**	**2%**	**12%**
Los Alamos	11,909	89%	<1%	1%	4%	3%	2%	12%
Rio Arriba County	**41,190**	**56%**	**<1%**	**14%**	**<1%**	**26%**	**3%**	**73%**
Chama	1,199	68%	2%	3%	<1%	25%	3%	71%
Española	9,688	68%	1%	3%	<1%	26%	3%	84%
Sandoval County	**89,908**	**65%**	**2%**	**16%**	**1%**	**12%**	**3%**	**29%**
Bernalillo	6,611	60%	1%	4%	<1%	31%	4%	75%
Cuba	590	44%	<1%	27%	1%	24%	4%	60%
Jemez Springs	375	78%	0%	2%	2%	5%	13%	27%
San Ysidro	238	31%	1%	8%	<1%	54%	7%	72%
Rio Rancho	51,765	78%	3%	2%	1%	11%	4%	28%
Santa Fe County	**129,292**	**74%**	**1%**	**3%**	**1%**	**18%**	**4%**	**49%**
Santa Fe	62,203	76%	1%	2%	1%	15%	4%	48%
Edgewood	1,893	87%	<1%	2%	<1%	8%	2%	20%
Sierra County	**13,270**	**87%**	**<1%**	**1%**	**<1%**	**8%**	**3%**	**26%**
Elephant Butte	1,390	92%	<1%	2%	<1%	5%	1%	13%
T or C	7,289	85%	1%	2%	<1%	9%	3%	27%
Williamsburg	527	92%	2%	1%	<1%	2%	4%	13%
Socorro County	**18,078**	**63%**	**1%**	**11%**	**1%**	**20%**	**4%**	**49%**
Magdalena	913	63%	1%	10%	0%	5%	22%	48%
Socorro	8,877	66%	1%	3%	2%	23%	5%	55%
Taos County	**29,979**	**64%**	**<1%**	**7%**	**<1%**	**25%**	**4%**	**58%**
Questa	1,864	50%	<1%	1%	<1%	6%	43%	81%
Red River	484	93%	0%	1%	0%	3%	4%	9%
Taos	4,700	68%	1%	4%	1%	22%	5%	54%
Valencia County	**66,152**	**67%**	**1%**	**3%**	**<1%**	**24%**	**5%**	**55%**
Belen	6,901	68%	1%	2%	<1%	26%	4%	69%
Los Lunas	10,034	64%	1%	3%	1%	4%	28%	59%
TEXAS	**20,851,820**	**71%**	**12%**	**1%**	**3%**	**12%**	**2%**	**32%**
El Paso County	**679,622**	**74%**	**3%**	**1%**	**1%**	**18%**	**3%**	**78%**

Region	Total Population	White	Black	American Indian	Asian	Other Race	More Than One Race	Hispanic or Latino
El Paso	563,662	73%	3%	1%	1%	18%	3%	77%
Fabens	8,043	74%	1%	1%	<1%	22%	3%	96%
Hudspeth County	**3,344**	**87%**	**<1%**	**1%**	**<1%**	**9%**	**2%**	**75%**

Note: Columns do not total due to rounding and due to some double-counting of ethnic and racial populations.

Source: Census 2000a,b, c

To evaluate the relative income of each county, selected municipalities, and New Mexico pueblos in the study region, income and poverty rates for each were compared to their respective states. Those areas with income that is 70 percent or less than the state average and at least double the state poverty rate average are shown in **Table 3-13**.

Table 3-13. Comparison of Income and Poverty Rates to State Averages

County/Municipality	70% or Less Than State Median Household Income	70% or Less Than State Per Capita Income	At Least Double the State Poverty Rate
COLORADO			
Alamosa County	✓	✓	✓
Alamosa	✓	✓	—
Conejos County	✓	✓	✓
Costilla County	✓	✓	✓
Rio Grande County	✓	✓	—
Monte Vista	✓	✓	—
Saguache County	✓	✓	✓
NEW MEXICO			
Doña Ana County	—	—	✓
Hatch	✓	—	✓
Las Cruces	—	—	✓
Sunland Park	✓	✓	✓
Rio Arriba County	—	—	✓
Española	—	—	✓
Sandoval County	—	—	✓
Bernalillo	—	—	✓
Cuba	✓	✓	✓
Jemez Springs	—	—	—
Sierra County	—	—	✓
T or C	✓	—	✓

County/Municipality	70% or Less Than State Median Household Income	70% or Less Than State Per Capita Income	At Least Double the State Poverty Rate
Williamsburg	✓	—	—
Socorro County	✓	—	✓
Magdalena	✓	—	✓
Socorro	✓	—	✓
Taos County	—	—	✓
Questa	✓	—	✓
Taos	—	—	✓
Valencia County	—	—	—
Belen	—	—	✓
TEXAS			
El Paso County	—	✓	·
El Paso	—	—	✓
Fabens	✓	✓	✓
Hudspeth County	✓	✓	—

Source: Derived from Census 2000a,b,c

3.14 Other Resources Considered

3.14.1 Air Quality

The National and New Mexico ambient air quality standards are listed in **Table 3-14**. In the New Mexico portion of the planning area, Doña Ana County is designated by EPA as a nonattainment area for failure to meet 10 micron particulate matter (PM10) and 1-hour ozone National Ambient Air Quality Standards (NAAQS). In the Texas portion of the planning area, El Paso County is in nonattainment for carbon monoxide, ozone (1-hr), and PM10. No Colorado counties in the planning area are in nonattainment for any pollutant.

Table 3-14. National and New Mexico Ambient Air Quality Standards

Pollutant	Averaging Time	NM Standards	National Standards
Ozone	1 hr	—	0.124 ppm
	8 hr	—	0.084 ppm
Carbon monoxide	1 hr	13.10 ppm	35 ppm
	8 hr	8.70 ppm	9 ppm
Nitrogen dioxide	annual	0.05 ppm	0.053
	24 hr	0.10 ppm	—
PM_{10}	annual	—	50 µg/m^3
	24 hr	—	150 µg/m^3
Sulfur dioxide	annual	0.02 ppm	0.03 ppm
	24 hr	0.10 ppm	0.14 ppm
Lead	quarter	—	1.5 µg/m^3

Sources: EPA 2004; NMED 2004

The major air pollutants at the various reservoirs are particulate matter in the form of windblown fugitive (transitory) dust. Under normal conditions, blowing dust in the general area depends on wind speed and soil moisture content. Local dust sources adjacent to reservoirs include the exposed, drying lake bed at the reservoir edges, recreational vehicles driving on dirt roads, and wind blowing over barren areas. Some of the existing air quality impacts at the reservoirs considered in this Review and EIS are from recreational ground and water vehicles and depend on the location of individual recreation facilities and management of those facilities, rather than from reservoir level fluctuations. As the area is currently responding to record drought and reservoir levels are historically low, reservoir recession has exposed large areas of the reservoir with subsequent invasion by vegetation. The vegetative cover helps stabilize sediments, reduces wind speed and exposed dust surface, and adds to habitat used by wildlife.

3.14.2 Noise

The lands adjacent to the reservoirs and rivers are relatively undeveloped, except where the river bisects established municipalities. Dominant sounds in the project area originate from natural sources: water, wind, and wildlife. Local traffic noise is generated by various highway crossings. Noise levels and patterns at developed recreation areas and frequently-used informal use areas are localized and typical of campground and day use recreational areas. Beyond these formal and informal recreation areas, the most conspicuous noise producers are power boats and jet skis on the reservoirs that allow these activities. noise levels above 85 decibels (dB) will harm hearing over time. Noise levels above 140 dB can cause damage to hearing after just one exposure. **Table 3-15** lists common noises and their decibel levels for reference.

Table 3-15. Points of Reference for Noise

dB or Decibels	Activities
1	The softest sound a person can hear with normal hearing
9	normal breathing
29	soft whisper
40	quiet residential area
50	rainfall
60	normal conversation
70	freeway traffic
80	whistling kettle
85	heavy traffic, noisy restaurant
90	truck, shouted conversation
95-110	motorcycle
100	snowmobile
110	busy video arcade
110	car horn
112	personal cassette player on high
120	thunder
125	chain saw
130	stock car races
150	jet engine taking off
162	fireworks (at 3 feet)
170	shotgun

Source: LHH 2001

3.14.3 Toxic or Hazardous Materials

Toxic and hazardous materials sites in the planning area include waste transportation, storage, treatment, and disposal facilities potentially exposed to flooding, scour or other damage. Examples of such facilities include pipeline river crossings and municipal sewage treatment facilities. Possible facilities of concern include: pipelines transporting compressed natural gas (CNG) and liquefied petroleum gas (LPG) that may become exposed with excessive river scour, downcutting, or erosion. If such damage occurred, the CNG would be considered an airborne hazard and LPG would become a waterborne petroleum contamination hazard.

3.14.4 Seismicity

The Rio Grande rift in north-central New Mexico and south-central Colorado was created by seismic action associated with the Laramide structural uplift, known for creating the Rocky Mountains. In the valley of the Rio Grande and Rio Chama, this uplift is manifested as a series of structural basins arranged in a right-stepping, en echelon pattern, with high heat flow, abundant late Quaternary faults and volcanism, as well as thick accumulations of basin sediments. It is these sediments that form the aquifer conditions that create a river basin of interconnected groundwater and surface water. Historical seismicity shows over 100 faults in the rift, with at least 20 exhibiting evidence for movement in Holocene (past 15,000 years) time (Wong et al. 2004). Besides naturally-occurring seismic events, reservoir-induced seismicity upon initial filling where storage depths exceed 80 to 100 meters (Allen 1982) and the seasonal recharge of groundwater through snowmelt events at higher elevations (Saar and Manga 2003) are reported to be able to trigger seismic events in some cases.

In this Review and EIS, no new facilities are being constructed. The proposed operational changes are for facilities in New Mexico, both on the Rio Chama and the Rio Grande above Elephant Butte reservoir. Seismic impacts, if any, are limited to the impacts of emptying and refilling these facilities, as most of the melting snow effects are in the project area where no changes in operations are proposed. Areas mapped with Holocene (less than 15,000 years) fault movement (Wong et al. 2004) do not underlie these facilities. As noted earlier, this Review and EIS proposes changes for existing facilities, which means that initial reservoir filling has already occurred. No reservoir-induced seismic events are known to have occurred when these reservoirs were initially filled.

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Chapter IV

Impacts of Water Operations Alternatives

4.1 Introduction

This chapter describes the impacts of the water operations alternatives on the resources discussed in Chapter 3. Analysis of impacts is conducted to estimate the amount of potentially significant change that a given resource might experience. Changes to a resource are considered from multiple perspectives including: 1) how much change is expected, 2) whether the change is beneficial or detrimental, 3) our understanding of complex relationships in the system, and 4) the reliability of the results of the analysis.

The upper Rio Grande basin is a complex system composed of interdependent relationships. Water present in the river at any given time is the result of many factors, including influences from snow pack, precipitation, drought, moisture deficit, evaporation, seepage, river bed geometry and composition, local geology, surface and groundwater diversion, return flows from irrigation and municipal uses, and other factors. Factoring in analyses of aquatic and riparian ecosystems adds further layers of complexity. Because such a large number of variables are possible, several computer models and spatial analysis tools (described in Chapter 2) were used to evaluate the amount of change that might be expected by implementing a proposed alternative. However, the results of these analyses can present conflicting impacts—for example, extremely high flows may benefit riparian habitat while potentially destroying cultural resource sites. When competing objectives and conflicting resource management goals occur, selecting an alternative that provides the best balance is a complicated process.

Decisions made in partnership are more complex than those made by individuals, as different objectives, agency missions, facility purposes, legal requirements, and management goals must be reconciled with human and ecosystem needs. The joint lead agencies (JLA) and cooperating agencies recognize that important decisions about Federal facility operations along the Rio Grande should not be made in isolation, but should involve an open, participatory, and consensus-building process. The JLA decided to implement a formal decision structure for evaluating alternatives in this Water Operations Review (Review) and Environmental Impact Statement (EIS). The decision structure is described in this section and detailed in Appendix P.

4.2 Methods, Tools, and General Assumptions

Decision-support software was selected to facilitate the documentation, analysis, and sharing of decision-making information for this Review and EIS. Criterium Decision Plus^{TM} (CDP) 3.0 (InfoHarvest 2001), available as a free model reader from www.InfoHarvest.com, was selected based on its ease of use. The graphical depiction of decision structure, tradeoff analyses, and uncertainty evaluations enable interested stakeholders to understand the reasons for the ranking of alternatives.

Structuring a formal decision process forces discipline in framing the problem and allows a complex decision to be broken down into manageable parts. The CDP software assists in analyzing the important and sensitive elements of a decision, in evaluating the robustness of the choice made, and in identifying the tradeoffs made in selecting the preferred alternative. When the decision results are finalized, there is a record of how and why a decision was made. **Figure 4-1** depicts the elements in a multi-criterion decision process.

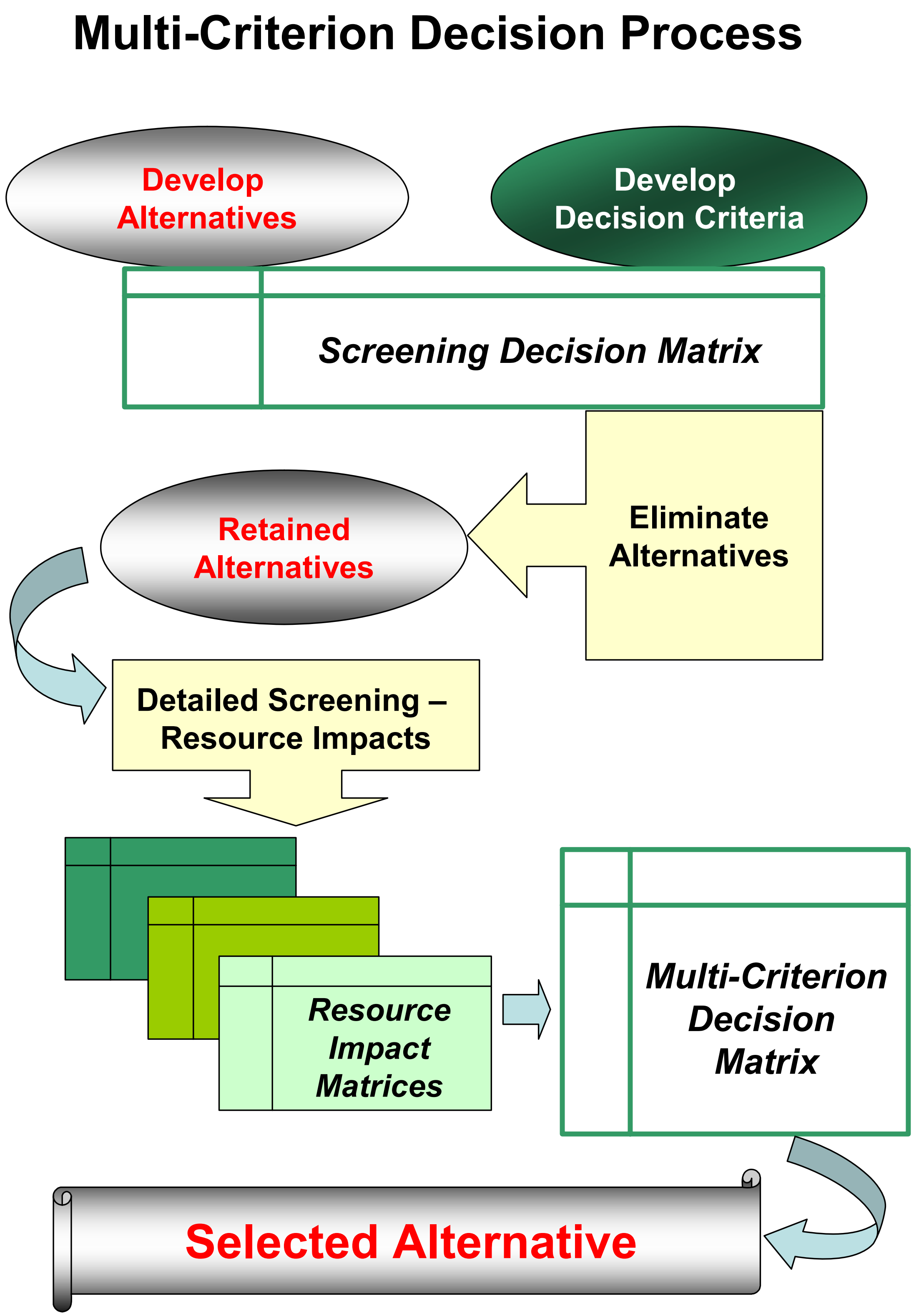


Figure 4-1. Elements in a Multi-Criterion Decision Process

Decision criteria and the relative importance of these criteria were established by the JLA, cooperating agencies, Steering Committee (see Figure 1-1), and other stakeholders prior to the analysis of alternatives and resource impacts. It was hoped that constructing and valuing the decision hierarchy as the first step minimized bias or prejudgment of alternatives. The resource teams then conducted the performance analysis of each alternative in accordance with the technical performance measures supporting the established decision structure. In order to maintain objectivity in resource team evaluation, alternatives were not identified by subjective names, but were instead identified only by letter and number. CDP was then used to document the alternative that best fit the stated hierarchy of decision criteria.

Effective decision criteria are directional, concise, clear and comprehensive, yet not redundant. The selected decision criteria considered the multitude of JLA requirements for environmental and regulatory compliance; multiple objectives in water management; multiple purposes for which facilities are authorized and operated; and stakeholder comments concerning resource impacts and issues. The JLA, Executive Committee, and the Steering Committee had opportunities to review, comment, and assign values to the proposed decision criteria.

The JLA identified three threshold criteria which an alternative needed to satisfy in order to be among those considered for implementation. The three overarching threshold criteria were:

- Meets Flood Control and Safe Dam Operations
- Meets Interstate Compact and Treaty Requirements
- Meets Water Storage and Delivery Needs

Nine decision criteria (**Table 4-1**) were then established for detailed analysis of the six action alternatives and the No Action Alternative. These decision criteria were developed from the Purpose and Need Statements for this Review and EIS and are based on the often competing regulatory requirements concerning natural and human environmental quality and health, cultural and tribal resources protection, and land use and socioeconomic considerations. These decision criteria were ranked in importance by the JLA, Steering Committee, and stakeholders. Three techniques for eliciting preferences among criteria were used. The first technique allocated 100 points across the nine criteria. The second technique established independent values for each criterion on a scale of 1 (low) to 10 (high). The final technique ranked the relative importance of each criterion compared to the others from high (1) to low (9). The average results across all three methods were used to establish the ordinal criteria rankings with the results from the JLAs and Steering Committee shown in **Table 4-1**.

Table 4-1. Ranking EIS Decision Criteria

AGENCY or STAKEHOLDER: JLA & Steering Committees Combined
Date: 11/13/2003
Participants: COE, BOR, ISC & Steering Committee Participants

FINAL RANKINGS	DECISION CRITERION	Fixed Point Criterion Score (Numerical)			Scaled Criterion Rating (Independent)			Ordinal Criterion Rank (Relative)			OVERALL RANK
		JLAs	SC	RANK	JLAs	SC	RANK	JLAs	SC	RANK	
A	Meets Water Storage & Delivery Needs	Threshold			Threshold			Threshold			EQUAL
B	Meets Interstate Compact & Treaty Requirements										EQUAL
C	Meets Flood Control & Safe Dam Operations										EQUAL
1	Meets Ecosystem Needs	15	20	2	7.7	8.8	2	1.7	1	1	1
4	Provides Sediment Management	13	12	4	6.0	6.4	4	3.3	3	3	4
3	Preserves Water Quality	17	15	1	6.7	8.6	3	4.0	2	4	3
2	Provides System Operating Flexibility	15	12	3	8.7	8.1	1	2.7	5	2	2
7	Preserves Desirable Land Uses	4	8	8	4.7	6.9	6	7.7	4	7	7
8	Preserves Recreational Uses	9	6	7	4.0	5.4	8	7.3	9	8	8
6	Preserves Cultural Resources	12	7	5	4.7	4.8	7	6.0	8	6	6
9	Alternative is Fair and Equitable	4	9	9	3.3	5.4	9	8.7	7	9	9
5	Preserves Indian Trust Assets	11	9	6	5.3	6.3	5	3.7	6	5	5

ABBREVIATIONS:
URGWOPS = Upper Rio Grande Water Operations
EIS = Environmental Impact Statement
JLAs - Joint Lead Agencies
COE = U.S. Army Corps of Engineers
BOR = U.S. Department of Interior - Bureau of Reclamation
ISC = New Mexico Interstate Stream Commission
SC - Steering Committee - input from participants in November 13, 2003 meeting choosing to participate in ranking

4.3 Scope of Analysis

There are physical, biological, and economic variations and uncertainties inherent in the operation of Federal facilities on the Rio Grande. The needs of a natural ecosystem are not necessarily the same as, or on the same schedule as, the delivery and use of water for human needs. Interrelationships in the ecosystem are not well understood. Attempts to improve or maximize a single resource can be too narrowly focused and can have unintended consequences, resulting in variable success for a given solution. Other factors that can contribute to uncertainty include extremes in precipitation and stream flow, seasonal and annual changes in water demand, and the various temporal and spatial scales available for measurement.

Limited modeling resources confined the Upper Rio Grande Water Operations Model (URGWOM) runs to exploring operating impacts that maximize available flexibility within the framework of the alternatives analyzed. For example, when native storage in Abiquiu Reservoir was allowed to reach a maximum of 180,000 acre-feet (AF), URGWOM was set up to allow storage to be maximized whenever possible. Similarly, if the diversion capacity for the Low Flow Conveyance Channel (LFCC) was 2,000 cubic feet per second (cfs) under a specific alternative, URGWOM allowed water to be diverted to the LFCC whenever it was available beyond the 250 cfs assumed bypass at the San Acacia Diversion dam. Thus, initial planning model results afforded a view of the maximum possible impacts of storage and diversion under a given alternative.

An initial analysis was performed modeling the No Action Alternative with zero diversions to the LFCC. These zero diversion data from the No Action modeling were used as input to other models including the aquatic habitat, riparian vegetation inundation, and hydraulic analyses. Sensitivity analyses were subsequently performed for the No Action Alternative that evaluated several diversion capacities including 500, 1,000, and 2,000 cfs to allow direct comparison with action alternative performance associated with LFCC diversions in the San Acacia Section. While the 40-year URGWOM runs were not completed for each variation of diversions to the LFCC under the No Action Alternative, the sensitivity analyses on the San Acacia section facilitate comparisons with the action alternatives.

The analyses performed by each resource team considered resource impacts in the context of available data and our current understanding of ecosystem dynamics. Expanding on the three threshold and nine decision criteria shown in Table 4-1, the decision hierarchy used in the decision support software for selecting the preferred alternative is shown in **Figure 4-2**. Alternatives were ranked according to how well they met each of the criteria to the left.

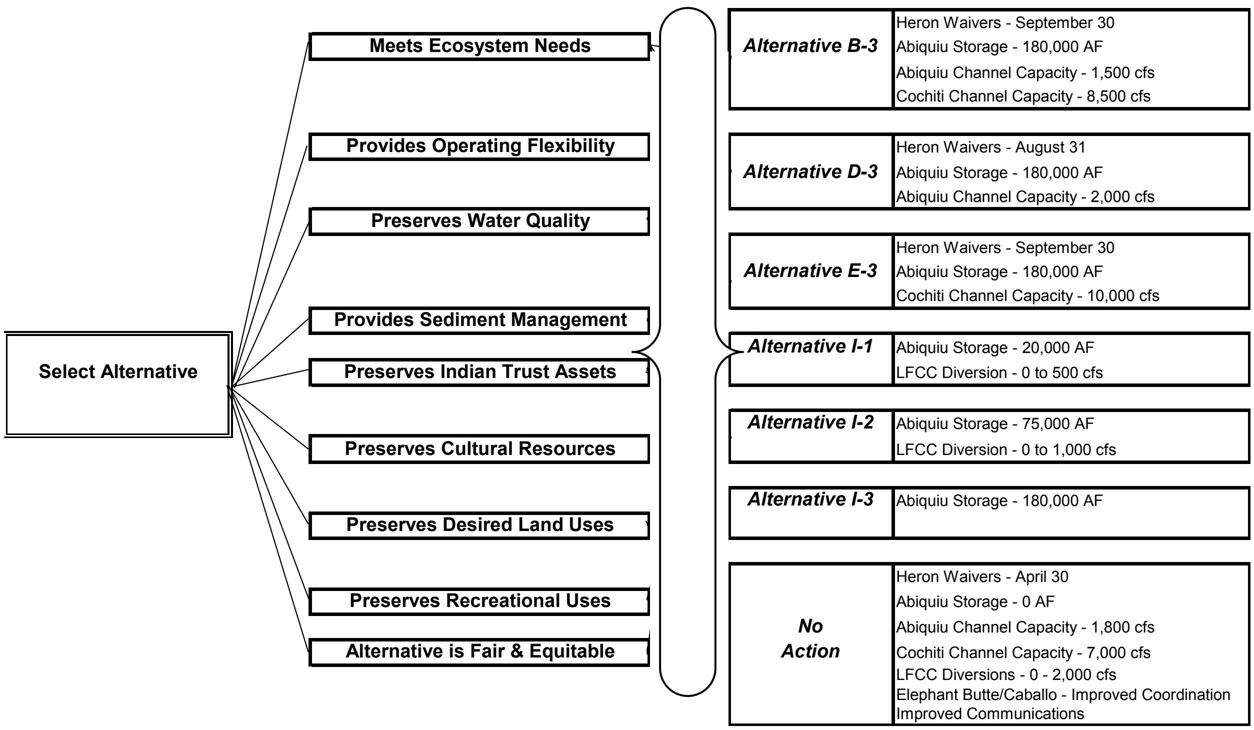


Figure 4-2. Decision Hierarchy

An evaluation of the quality of the data was used to supplement the decision criteria, effects analyses, and resource- and reach-specific conclusions. Each technical team documented datasets used, the corresponding metadata (data about the data, such as who, what, where, how collected, etc.), and rated the relative quality of each dataset within the applicable river reaches. This information was imported into a database to facilitate organizing the data quality by resource, reach, river section, or other parameters. The intent of the data quality database is to disclose the individual and overall quality of the datasets used in the evaluation of alternatives, to identify areas where data are insufficient or lacking, to identify data that may require adaptive management or future study, and to assist decision makers in understanding the comparison of alternatives in the context of the limitations of the data. The data quality, uncertainties, and gaps are further explored in Appendix P.

Each resource team was responsible for conducting a technical evaluation of the condition of the resource; establishing performance measures and analyses to evaluate alternative impacts; performing an assessment of the relative importance among competing criteria describing their resource; performing an assessment of the spatial and temporal variability, data gaps, and other sources of uncertainty inherent in their analysis; and developing and scoring the decision matrix for criteria. The results of these analyses are described by alternative and resource at the end of this chapter.

4.4 Affected Resources

The impacts of proposed water operations alternatives were analyzed by the resource teams using information from various sources: 1) URGWOM-planning model simulation of each alternative, assuming the most conservative implementation (i.e., if LFCC diversion or conservation storage was allowed up to a given limit, the model always simulates diversions up to that limit); 2) URGWOM planning model sensitivity analyses that evaluated alternative performance under a subset of the allowable range (i.e., No Action under various LFCC diversions); 3) database and spatial analysis via the GIS tools; and 4) specialized models specific to each resource, such as the aquatic habitat model, the San Acacia surface water/groundwater flow model (MODBRANCH), and 5) simple analytical and empirical models or calculations. For all cases, the same 40-year hydrograph and starting reservoir conditions were used.

Resources evaluated for changes included hydrologic and geomorphologic variation; aquatic and riparian ecosystem, water quality, Indian trust assets, cultural resources, various land uses – including agricultural and recreational uses; hydropower; flood control; and the regional economy. Alternative impacts by resource are discussed in the following sections.

4.4.1 Hydrology and Geomorphology

The primary changes that occur with alternative water operations are expressed as changes in water flow and reservoir storage. The changes in flow can also cause changes in geomorphology as sediments are moved and deposited along the river channel.

4.4.1.1 Issues

The primary goal for this EIS was to evaluate alternative operations within the constraint of existing authorities in order to better coordinate and manage water in the river system. Consequently, the alternative selected must meet minimum standards for three threshold criteria: safe operations, ability to meet water deliveries, and ability to meet Compact and Treaty obligations.

Safe dam operations were modeled using existing operating rules. These rules prevent water releases or storage that could exceed operating practices. Days at channel capacity (normal maximum flow) were used to evaluate the relative safety of operations among the different alternatives. Prolonged durations (more than 1 month) at channel capacity were deemed undesirable due to ancillary effects on levees, diversion structures, and agricultural lands. Alternatives D-3, E-3, I-3, and I-2 offered improvements in duration at channel capacity. **Figures 4-3 and 4-4** show days at channel capacity below Abiquiu and Cochiti dams, respectively. Alternatives B-3 and I-1 performed similar to No Action, with extended durations at channel capacity below Abiquiu Dam occurring in 17 of 40 years. Days at channel capacity below Cochiti all showed improvements among the action alternatives as compared to no action considering a channel capacity of 7,000 cfs. Alternatives B-3 and E-3 had zero days at their proposed channel capacities of 8,500 and 10,000 cfs, respectively.

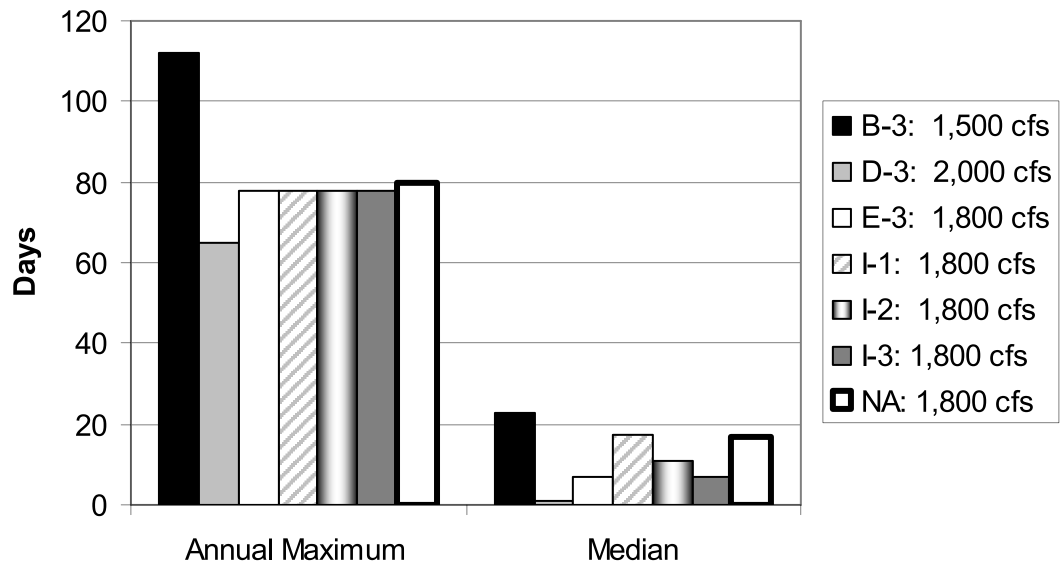


Figure 4-3. Days at Channel Capacity below Abiquiu Dam over 40-Year Planning Period

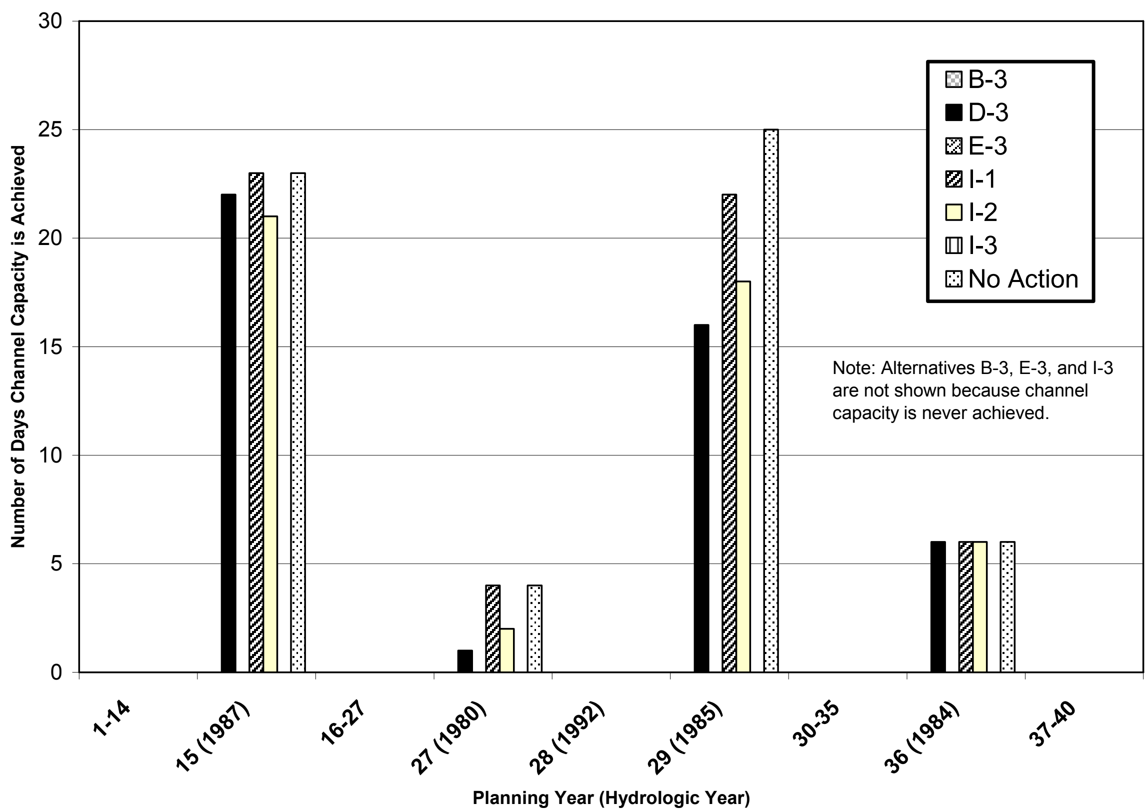


Figure 4-4. Days at Channel Capacity below Cochiti Dam over 40-Year Planning Period

In the Southern Section, flood control protocols for Elephant Butte Reservoir were invoked only when reservoir storage exceeded 2 million AF. This condition was predicted to occur only 9 days over the 40-year period. For this reason, impacts from changes in water operations for the Southern Section related to implementation of flood control protocols were not significant.

Heron Reservoir firm yield was used to evaluate water storage for contracted water deliveries. Firm yield is the amount of water that can be provided by a basin and reservoir system with reasonable certainty each year. As shown on **Figure 4-5**, all alternatives retained for detailed analysis were able to support the firm yield of 96,200 acre-feet per year (AFY). Annual median storage at Heron Reservoir is more than 240,000 AFY across the 40-year planning period. The 15th percentile daily storage values under all alternatives approximate the firm yield and occur across alternatives during the dryer years when reservoir levels are drawn down due to downstream demand. The 15th percentile daily storage under Alternatives B-3 and D-3 is slightly below the San Juan-Chama Project firm yield of 96,200 AFY.

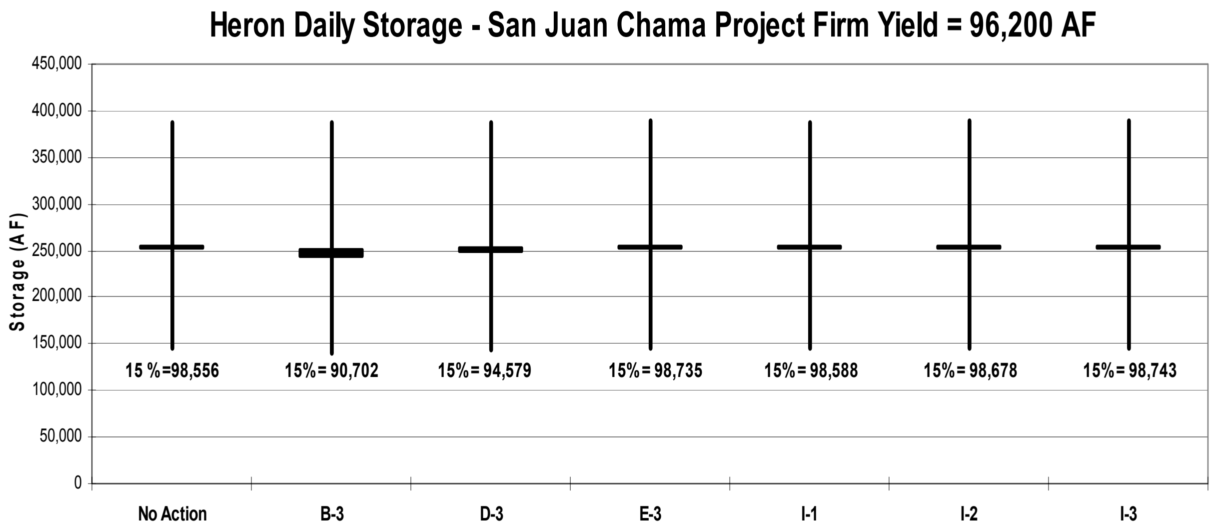


Figure 4-5. Heron Reservoir Storage by Alternative

Compact deliveries were further used to distinguish alternatives, as they differ in their ability to meet New Mexico's Compact obligations. This ability is impacted by both the upstream storage and release pattern of native conservation water and the efficient delivery of water through the San Acacia Section. As shown on **Figure 4-6**, alternatives that maximize storage and possess the largest diversion capacities in the LFCC are the alternatives that maximize Compact deliveries and provide a more favorable credit status. While all alternatives provide a positive credit status at the end of the 40-year planning period, Alternatives I-1 and I-2 do not perform as well as the other alternatives.

While all alternatives offer improvements to New Mexico Compact credit status, Alternatives I-1 and I-2 do not meet threshold criteria for Compact deliveries due to lesser capacities of the LFCC and higher delivery losses incurred in the San Acacia section. Alternatives I-1 and I-2 also experienced extended accrued debit periods for Compact deliveries to Texas of 11 and 6 consecutive years, respectively. Under the No Action Alternative there were 13 consecutive years where New Mexico was in accrued debit status All other alternatives limited the accrued debit period to 4 years under the hydrologic sequence and release assumptions used in the modeling scenarios.

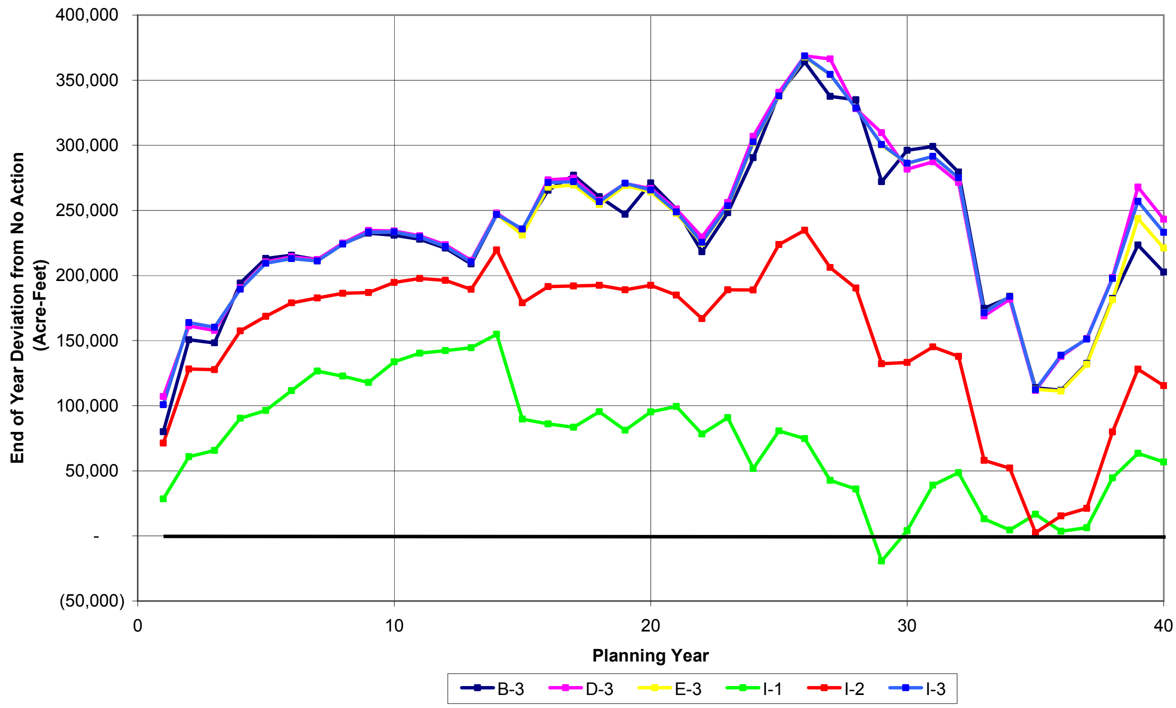


Figure 4-6. New Mexico Credit/Debit Status Compared to No Action

A summary of hydrologic performance regarding threshold criteria is provided in **Table 4-2**. Alternatives I-1, I-2, and No Action do not meet threshold performance criteria for Compact deliveries. However, these alternatives will be carried through in the detailed analysis in order to identify the range of impacts and evaluate mitigation needs as per the request of the National Environmental Policy Act (NEPA) Interdisciplinary (ID) team.

Table 4-2. Summary of Threshold Criteria Evaluation by Alternative

Parameter	Measure	Units	No Action (LFCC at 0 cfs)	B-3	D-3	E-3	I-1	I-2	I-3
THRESHOLD CRITERIA									
Safety of Dams	Set by URGWOM Planning Model Rules	NA	Met	Met	Met	Met	Met	Met	Met
Total Days at Channel Capacity	Below Abiquiu Dam (38 years out of 40)	Days/year	26	30	13	17	27	22	17
	Years where >30 days at channel capacity below Abiquiu	Years	17	17	7	9	17	11	9
	Below Cochiti Dam (4 years out of 40)	Days/year	15	0	11	0	14	12	0
Firm Yield – Heron Reservoir	15th Percentile Annual Storage (Target 96,200 AF)	AF	98,556	90,702	94,579	98,735	98,588	98,678	98,743
Compact Deliveries	Median New Mexico Compact Credit Status	AF	48,725	272,065	296,788	290,319	125,356	208,579	295,569

Notes: *Range of flows under No Action at LFCC Diversions of: 0, 500, 1,000, and 2,000 cfs.
** Range of flows under No Action LFCC Diversions not evaluated – comparisons reflect action of LFCC, not difference between alternatives at same level of NO Action diversion.

4.4.1.2 General Conclusions

Alternatives I-3, E-3, D-3, and B-3, listed in order of preference, offer the best performance for maximizing both native Rio Grande conservation storage in Abiquiu Reservoir and LFCC diversion relative to the three threshold criteria under the assumed release pattern: safe operations; ability to meet water deliveries; and ability to meet Compact and Treaty obligations. Despite exercising maximum potential to store and divert water, actual hydrologic inflow conditions limit storage and diversion during dry years. In many years, Rio Grande Compact restrictions further limit storage until downstream obligations are met. The alternatives maximizing conservation storage offer significant advantages in accommodating multiple uses, especially if year-to-year carryover is negotiated for stored water. The multi-year carryover offers the potential to provide a stored water reserve that can be tapped for multiple benefits during later dry years. By offering more options for water storage and management control, water releases could be used to maximize flood peaks and minimize periods of intermittency. However, the impact of carryover storage and different release patterns of the conservation pool on the threshold criteria was not evaluated in this EIS.

The I-2, I-1, and No Action Alternatives offer fewer opportunities for storage that reduce operating flexibility in managing water for multiple benefits, including deliveries to meet New Mexico Compact obligations.

Geomorphologic impacts were evaluated along the Rio Chama and Central and San Acacia Sections. Sediment volume decreases for all action alternatives as compared to the No Action Alternative. However, the computed change in bed elevation for the action alternatives is nearly identical to that of the No Action Alternative. Aggradation/degradation changes were insignificant as they were predicted to be on the order of hundredths of feet. Below San Acacia, impacts are related to diversions to the LFCC. Greatest diversions to the LFCC result in increased aggradation due to lesser river flows and less erosive energy along the banks.

4.4.1.3 Impact Indicators

The following indicators were used to evaluate hydrologic and geomorphologic impacts.

<u>Hydrologic Impacts</u>	<u>Geomorphologic Impacts</u>
Reservoir storage	Sediment Volume
Reservoir elevation change	Aggradation/Degradation Trends
Days at channel capacity	Erosion – Bank Energy Index
LFCC usage relative to available flow	
Water delivered for Compact compliance	
Peak discharge	
Availability of winter flows	

Methods of Analysis

Water operations and hydrologic impacts were evaluated using the URGWOM planning model. The URGWOM planning model includes the RiverWare surface water model as modified by inputs from the MODFLOW/MODBRANCH surface water/groundwater model developed for the San Acacia Section. Model documentation is provided in Appendix J. The URGWOM planning model simulates the hydrologic response to a change in reservoir operation, channel capacity, or water diversion based on defined physical characteristics of the system. Key assumptions concerning the physical system model included the following: 1) use of a single 40-year inflow hydrograph sequence of historical years; 2) initial use of 2001 reservoir storage conditions; 3) computed losses associated with seepage, evaporation, and transpiration from riparian vegetation along a given reach; 4) using an average year for the link to MODFLOW/MODBRANCH results in the San Acacia Section.

The policy impacts of operating within reservoir-authorizing legislation, Compact and Treaty obligations, imported and native water management, and other operating policy is a source of uncertainty. Rigid triggers for water operations management include limits on upper and lower reservoir storage that correspond to safe operating limits; seasonal flow requirements; Compact restrictions on storage in dry years; and other rules. Diversions by irrigators, municipalities, and other water users were assumed to continue per historic patterns and do not take population growth or year-to-year variability in irrigation demand into account. (See Appendix I.)

The URGWOM planning model was calibrated and sensitivity runs were performed to improve model performance relative to historic conditions documented by actual data. However, uncertainties do exist. Model results are provided at specific locations along the river that typically coincide with United States Geological Survey (USGS) stream gages. These gages have a calibration accuracy of about 5 percent. The model was used to compare alternative operations and evaluate resulting differences. However, the resulting flows are only available for key locations along the river and cannot be easily extrapolated to other locations.

The methods used to estimate geomorphic changes in the river are described in Appendix H, and include estimating changes in sediment volume, predicting aggradation/degradation, and evaluating erosion energy by using a bank erosion index.

Thresholds for Significance

Typically, deviations greater than 10 percent from No Action were examined for cause and identified as a potentially significant impact. However, flow records at key model gages were considered accurate within 5 percent, as this is the standard of calibration used by the USGS for actual gage data. Thus, changes in flow within 5 percent of No Action were not deemed significant.

4.4.1.4 Discussion of Results

To understand the impacts of changes in water operations, it is easiest to trace the flow from the upper Rio Grande watershed and progressively move down each river section (**Figure 4-7**). Flows along the Rio Chama are shown by the graphs on the left and flows on the Rio Grande are depicted by graphs along the right margin. These flows are in part dictated by the 40-year synthetic inflow hydrograph shown on Figure 2-1 in Chapter 2. No operational changes were proposed for facilities located in the Northern Section, thus typical monthly flows at Lobatos characterize main stem Rio Grande flows delivered from Colorado to New Mexico. Peak flows are shown by the patterned bar measured against the left-hand scale. The 75th/50th/25th percentile and average flows are shown against the right-hand scale. A percentile is a value on a scale of one hundred that indicates the percent of a distribution that is equal to or below it. The 50th percentile flow is the median, where half the flow records are above and half the flow records are below the median. The 75th percentile is above normal or in the high range of flows. The 25th percentile is below normal or in the low range. In the upper Rio Grande basin, the average monthly flow is typically higher than the median due to the large variability in the higher daily flows. Monthly flows delivered from Colorado to New Mexico at the Lobatos gage had a daily flow near 5,000 cfs, with a median daily flow of 288 cfs. All of the proposed changes to water storage occur along the Rio Chama—specifically modifications to Heron Reservoir waiver dates and various degrees of native Rio Grande conservation storage in Abiquiu Reservoir. Increases and decreases above the current channel capacity below Abiquiu were also considered.

Rio Chama tributary inflow is approximately one third of the total flow passing Otowi gage. Discussion of changes along the Rio Chama requires discussion of both flows and changes in reservoir storage. Changes in reservoir storage are shown on **Figure 4-8**. This figure shows the 75th/50th/25th percentiles and the average storage for each reservoir. Together with flow data reported on Figure 4-7, the effects of operational changes on flows and reservoirs can be evaluated.

Heron Reservoir Waivers: The greatest proposed change in water operations occurs at Heron Reservoir. Potential changes in San Juan-Chama Project water waiver dates include extending possible carryover of water in Heron Reservoir from April to August or September. Changing waiver dates allows water to be held back longer in the reservoir, without that water being lost to the contractor and reverting back to project storage. With the exception of decreased minimum storage under Alternative B-3, there were no significant impacts on 75th, 50th, and 25th percentiles in Heron Reservoir storage—maximum and minimum reservoir elevations are constrained by the model to account for operational safety. Significant impacts are defined as greater than 10 percent changes in storage from No Action.

As shown on Figure 4-8, impacts to Heron Reservoir pool elevation are expressed in rapid decreases under alternatives with August and September waivers exercised during dry years when upstream storage is restricted by Article VII of the Rio Grande Compact. Extended waiver dates show that a greater volume of San Juan-Chama water is transferred to El Vado Reservoir during the extended dry period. Additional transfers to El Vado Reservoir result in less water reverting to project storage during dry years. The total volume of water transferred is on the order of 6,000 to 7,000 AF over the entire 40-year period; however, these transfers occur during a dry decade when reservoir storage is already critically low.

Changes attributed to extending waiver dates include the ability to store more water in El Vado as indicated by significantly greater median reservoir storage under Alternatives B-3 and D-3 with September and August waiver dates, respectively. Alternatives E-3 and I-3 show smaller increases in El Vado storage suggesting that downstream native conservation storage in Abiquiu Reservoir may also result in increased ability to store water in El Vado. Daily flows below El Vado are decreased under Alternatives B-3 and E-3 suggesting that September waiver dates cause some shaving of flows along the Rio Chama. Average and median flows were essentially unaffected by extended waiver dates.

Average annual El Vado Reservoir elevation fluctuations are shown on Figure 4-8. The fluctuations in El Vado elevations are primarily related to the sequence of wet and dry years comprising the 40-year hydrologic sequence, rather than significant changes related to water operations. This is because all alternatives, including No Action, initiate storage in El Vado in a similar fashion starting near the same point each spring. However, during periods when Article VII storage restrictions are quickly lifted then enacted (model years 2037 through 2039), noticeable departures from the No Action Alternative are observed. Alternatives B-3 and E-3, with September waiver dates at Heron Reservoir, show the greatest annual elevation departures: about 10 to 20 feet higher than those expected under No Action.

Abiquiu Native Conservation Water Storage: Maximum storage observed in Abiquiu Reservoir is typically less than the maximums available under the 180,000 AF for all alternatives except B-3. With the lower channel capacity below Abiquiu Dam, Alternative B-3 has a higher duration of flow retention behind Abiquiu Dam resulting in higher total storage and native conservation water storage. Alternatives E-3, I-3, and D-3 are also favorable in providing conservation storage opportunities with mean storage near 100,000 AF. Alternatives I-2 and I-1 store about 84,000 and 62,000 AFY, but are constrained in maximum native water storage capacity to 75,000 and 25,000 AF, respectively. The No Action Alternative demonstrates water typically stored for flood control purposes only, ranging from about 45,000 to 62,000 AFY.

Water stored under the No Action Alternative is subject to Compact restrictions in its use and release (P.L. 86-645), unless specific annual deviations are obtained. The No Action Alternative has no provision for native conservation water storage. Frequency analysis of conservation storage in Abiquiu Reservoir was conducted over the 40-year planning period for the action alternatives (**Figure 4-9**). Results indicate that the opportunity to store conservation water in Abiquiu Reservoir would occur in about 21 of 40 years. Under Alternatives B-3, D-3, E-3, and I-3, the opportunity to store at least 100,000 AF in a given year would occur about 35 percent of the time.

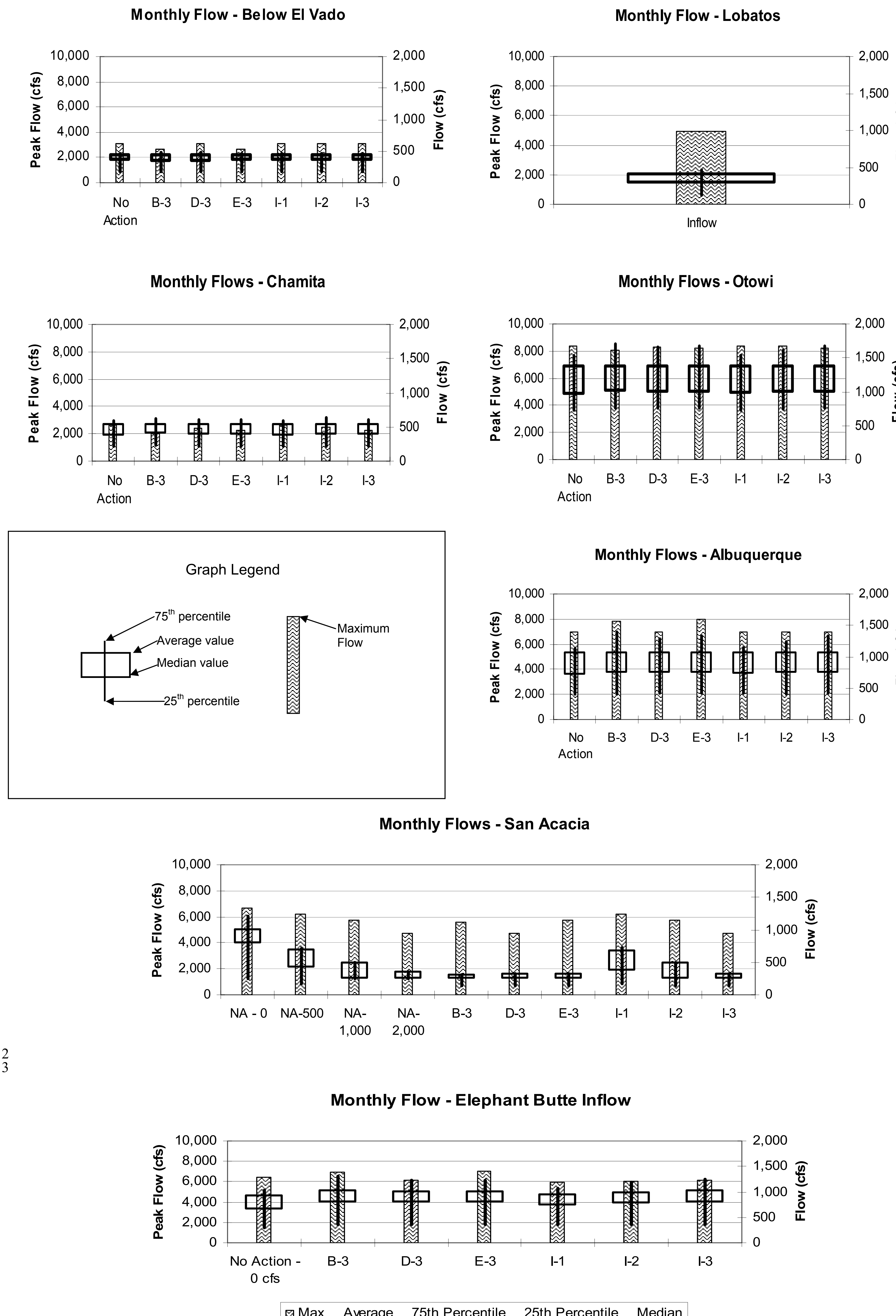


Figure 4-7. Flows at Gages along the Rio Chama and Rio Grande

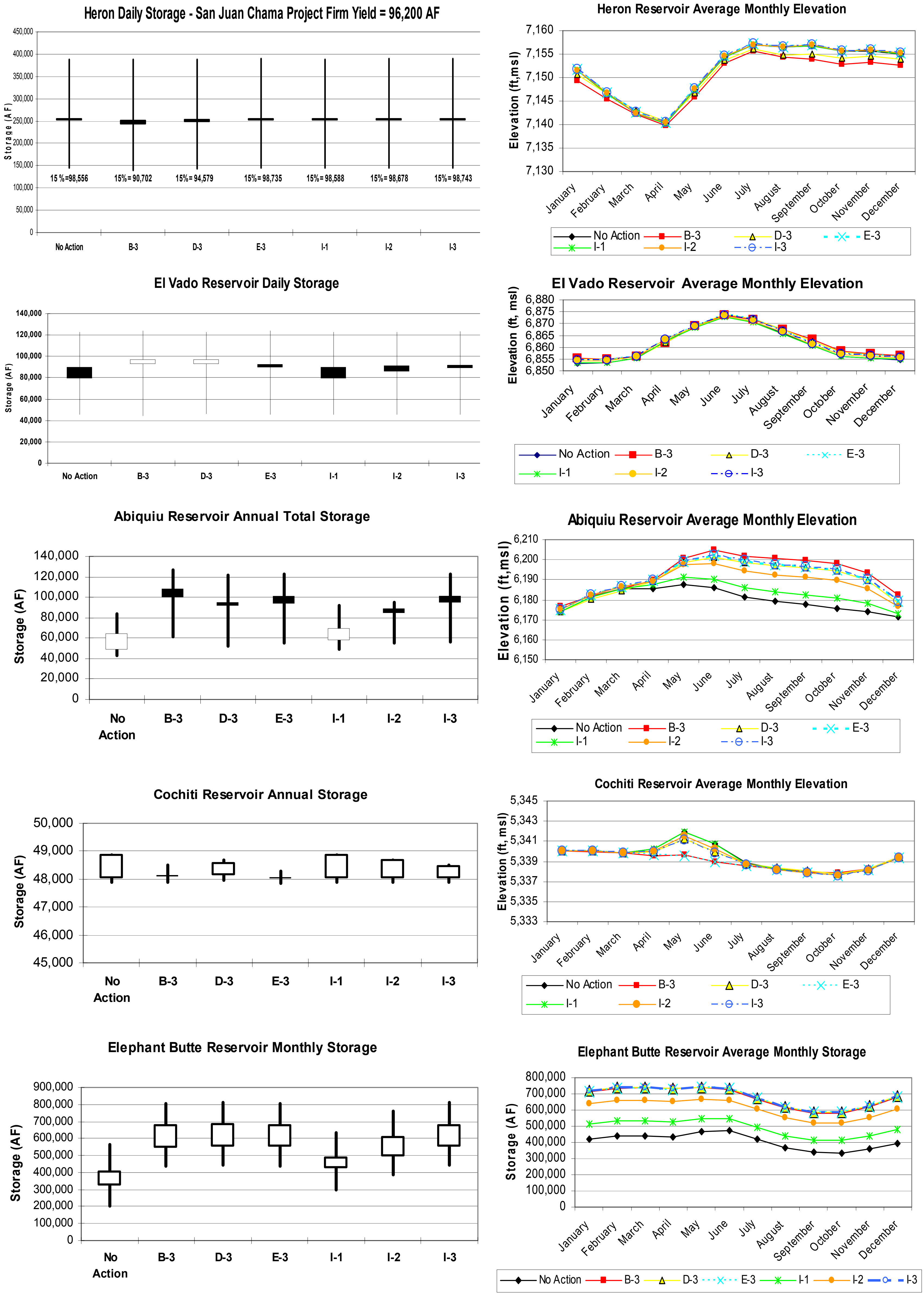


Figure 4-8. Reservoir Storage and Annual Elevation Fluctuations

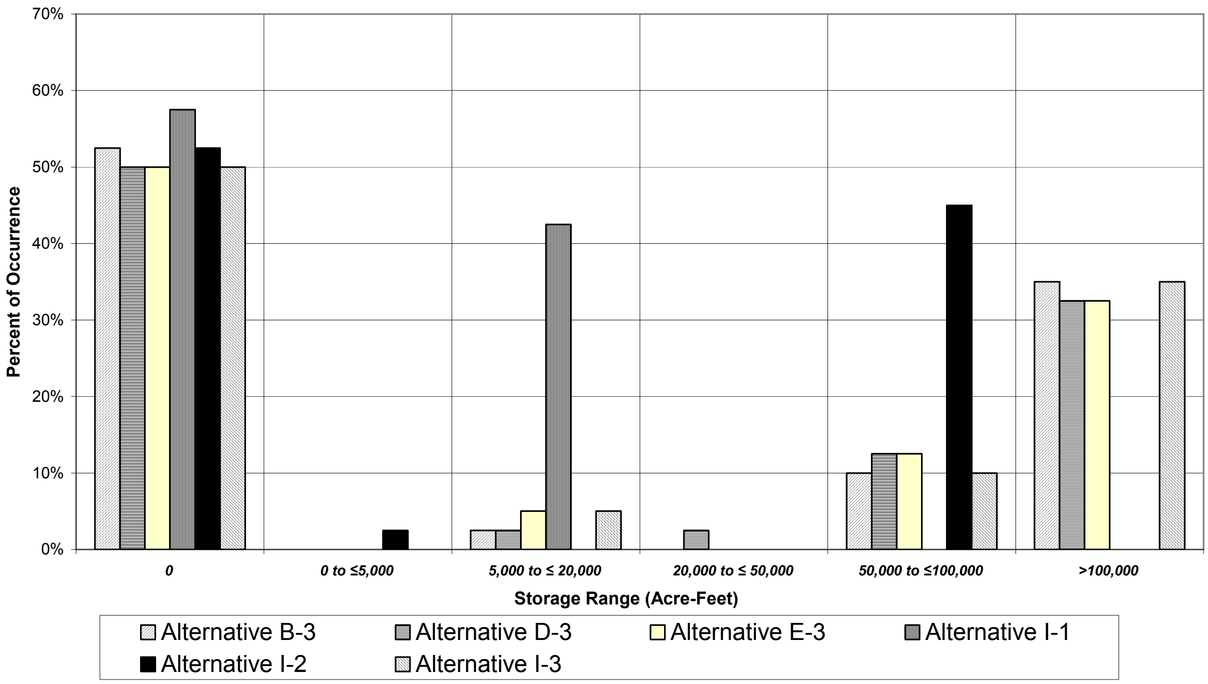


Figure 4-9. Percent of Occurrence of Conservation Storage in Abiquiu Reservoir

Native conservation storage was identified as water that could possibly be stored and used for the benefit of endangered species, ecosystem management, Compact deliveries, or other uses. However, the specifics regarding the release, year-to-year carryover, and other use of this water remain to be defined by specific agreements for storage in Abiquiu. In developing impact analyses for other resources, resource teams made different assumptions about how much of the native water stored in Abiquiu would be available and how it would be released.

Storage at Abiquiu and changes in downstream channel capacity result in small impacts on daily and percentile flow distributions at the Chamita gage. The alternatives storing the least water, No Action, I-1, and I-2 have the higher daily flows, but the $75^{th}/50^{th}/25^{th}$ percentile flows are similar among all alternatives. Increases in native conservation storage in Abiquiu result in a slight reduction in daily flows at the Chamita gage. As most storage impacts occur along the Rio Chama, frequency analysis of the Rio Chama flow at Chamita for all action alternatives (**Figure 4-10**) indicated that there would be a 10 to 20 percent reduction from the No Action Alternative for flow with a recurrence interval of 1.25 years. A recurrence interval is the probability that a flow event with the same intensity will be equaled or surpassed in the next year – for example, a 100-year recurrence interval indicates a 1 in 100 chance such an event would occur in the next year. The flow with a 10-year recurrence interval would be similar to those under No Action for all action alternatives except Alternative B-3, which would show a reduction of 15 percent. As Rio Chama inflows represent one-third of the flows at Otowi, changes at Otowi were typically less than the 5 percent variability expected from gage error alone, with the exception of slightly higher 75^{th} percentile flows under all alternatives except I-1 due to the release pattern used in the analysis.

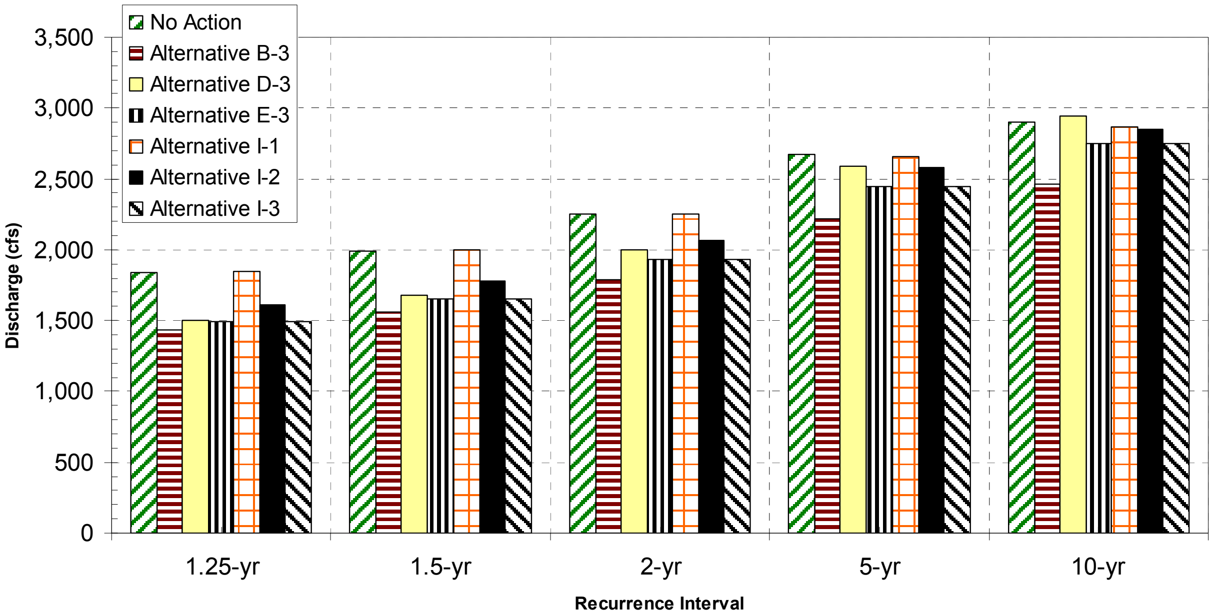


Figure 4-10. Frequency Analysis Summary of the Rio Chama at Chamita Gage under Each Alternative

Changes in geomorphology in the Rio Chama were evaluated, and there was no significant difference in sediment volume, aggradation/degradation trends, or bank energy indices among any of the alternatives in this section (See Appendix H).

Mainstem Rio Grande at Otowi: The impact of proposed operational changes along the Rio Chama into the Rio Grande main stem is examined by behaviors in monthly flows at Otowi gage. Significant (greater than 10 percent) impacts to flows were observed as increased 75th percentile flows under Alternatives B-3, D-3, E-3, I-3, and I-2. Presumably, higher levels of native conservation storage and the release of that water during November and December of each year result in the higher flows observed. Median flows increased under Alternatives B-3 and I-3. No other significant changes to flows at Otowi gage were observed for any of the alternatives.

Albuquerque Gage: Alternatives B-3, D-3, E-3, I-3, and I-2 all had increased 75th percentile flows passing the Albuquerque gage, presumably related to the release of native conservation storage in Abiquiu. Alternatives B-3 and E-3 also had significant increases in maximum daily flows due to the higher channel capacities below Cochiti Dam allowed under these alternatives. No other significant changes in flow were observed at the Albuquerque gage for any of the alternatives.

LFCC Diversions and Flow at San Acacia Gage: Flow analysis in the San Acacia Section first needs to consider the impacts under No Action resulting from varying levels of diversion into the LFCC. Daily flows vary by 2,000 cfs, which is equal to the maximum diversion allowed under No Action. All diversions to the LFCC were modeled assuming a minimum of 250 cfs would be left in the river channel, with no diversion allowed to the LFCC when river flows at San Acacia are less than 250 cfs. For example, if the flow at San Acacia is 1,250 cfs and the LFCC capacity is 500 cfs, 500 cfs would be diverted to the LFCC and 750 cfs would remain in the river channel. If flow at San Acacia is less than 250 cfs, there would be no diversions to the LFCC. Hydrology controls the maximum levels of diversions, demonstrated by the fact that the full 2,000 cfs LFCC capacity is used only 4 percent of the time and 75 percent capacity (1,500 cfs) is used only 14 percent of the time. While 100 percent of the annual river flow could potentially be diverted, only 49 percent of the flow is conveyed even with the maximum 2,000 cfs LFCC capacity due to the 250 cfs bypass assumption. **Figure 4-11** shows average annual diversions to the LFCC over the 40-year period. The data were limited only to the I alternatives because they represent the range of LFCC capacity applied in the model.

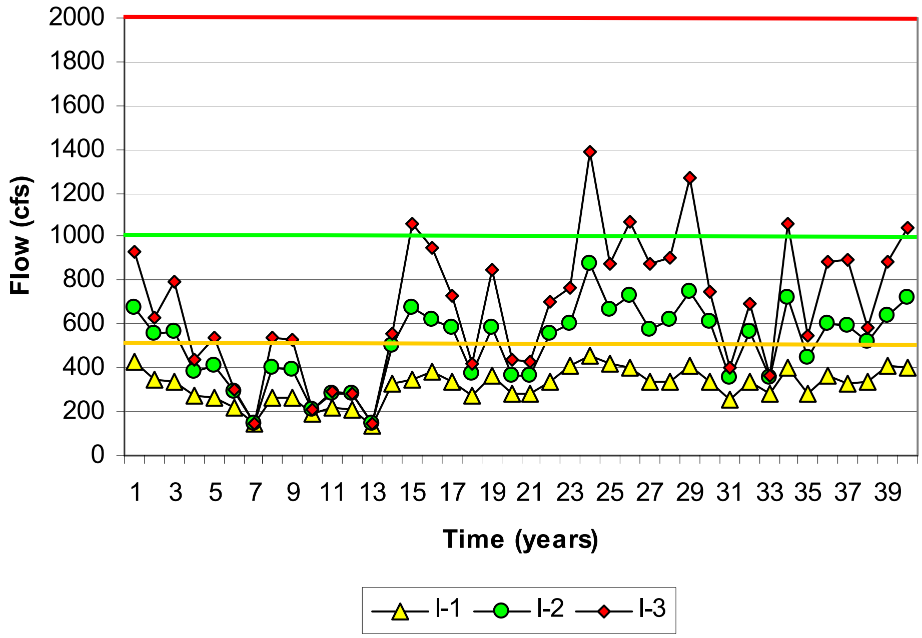


Figure 4-11. Average Annual LFCC Diversions

At the San Acacia gage (Figure 4-7), proportional decreases occur across the 75th/50th/25th percentile flows, depending on the level of LFCC diversion. Changes among alternatives were compared to the corresponding level of diversion under No Action. For example, changes under Alternative I-1 were compared to No Action at 500 cfs; changes in Alternative I-2 were compared to No Action at 1,000 cfs; and changes in Alternatives B-3, D-3, E-3, and I-3 were compared to No Action at 2,000 cfs. Flows predicted for No Action with zero diversion provides the highest river flows in the San Acacia Section.

Changes in flow at the San Acacia gage attributed to alternative water operations occur as follows:

- Maximum daily flows increased for Alternatives B-3 and E-3 due to higher channel capacities allowed below Cochiti Dam under these alternatives
- Alternative I-2 shows significantly higher 75th percentile flows compared to No Action at 1,000 cfs diversion, as a result of Abiquiu conservation storage releases
- Alternative I-1 has slightly lower 50th percentile flows than No Action at 500 cfs diversion
- Most alternatives show lower 25th percentile flows than No Action due to diversions into the LFCC

The only potentially significant changes in geomorphic indicators occurred between San Acacia and San Marcial (**Figure 4-12**) and were associated with the magnitude of diversion to the LFCC. Diversion to the LFCC decreased sediment transport, decreased river channel flow volume, and decreased erosive energy resulting in changes in aggradation/degradation when compared to No Action with zero diversions to the LFCC. It should be noted that active diversions to the LFCC under No Action were not explicitly evaluated. Thus, much of the change attributed to action alternatives is likely the result of implementing diversions to the LFCC.

Elephant Butte Inflow: Inflow to Elephant Butte Reservoir was used as a surrogate gage to evaluate flows into the Southern Section (Figure 4-7). Highest daily flows were recorded under Alternatives B-3 and E-3; lowest daily flows were observed under Alternatives I-1 and I-2. Alternatives D-3 and I-3 maintained higher flows than No Action in all flow categories (75th/50th/25th percentiles). Alternatives I-1 and I-2 had reduced daily flows when compared to No Action, but showed some improvements in flows in the middle and lower flow categories. Alternatives B-3, D-3, E-3, and I-3 all showed 10 percent improvements in average monthly flows over the 40-year period. Alternatives I-1 and I-2 had 3 percent and 7 percent improvements in average monthly flows as compared to No Action with zero diversions to the LFCC.

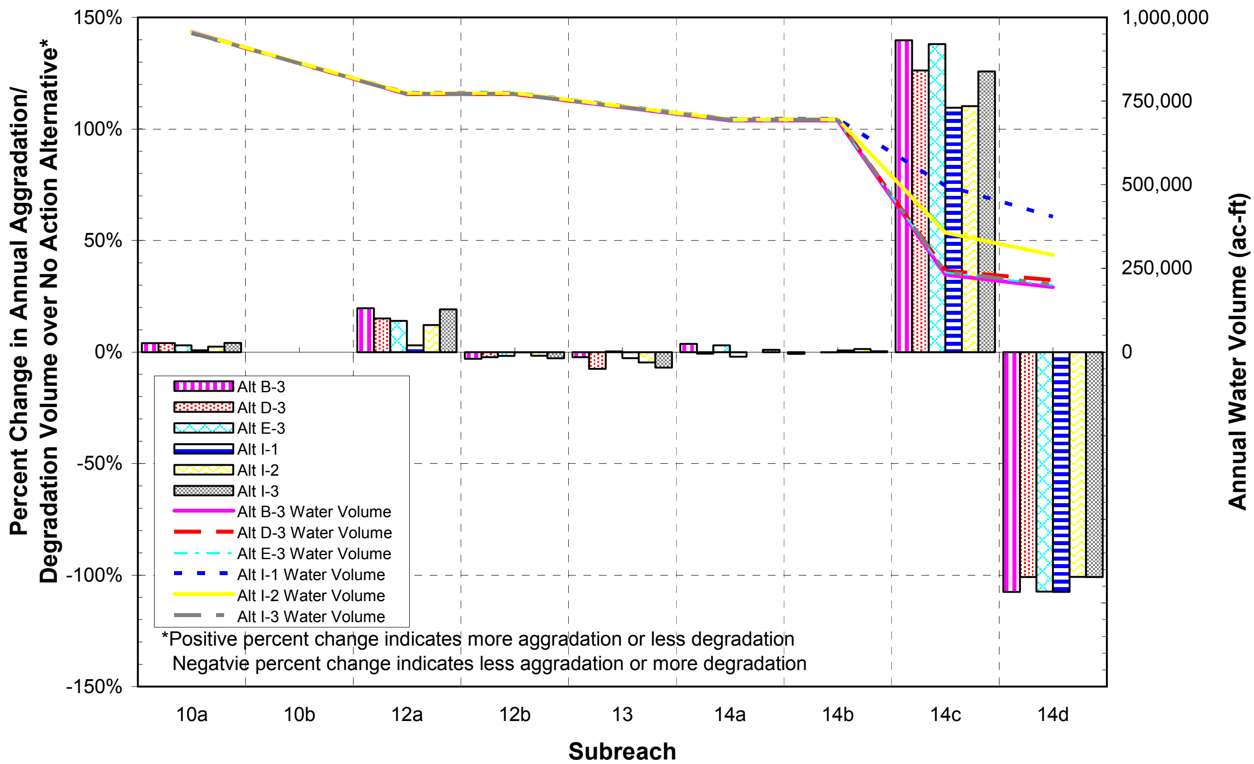


Figure 4-12. Changes in Aggradation/Degradation and Flow Volume

Flows in the Southern Section were not explicitly evaluated as flood operations in Elephant Butte and Caballo Reservoirs were not triggered by any of the alternatives during the 40-year analysis period.

Geomorphologic Analysis: The geomorphologic impacts for the No Action Alternative in the Central Section would remain degradational, although continued coarsening of the bed material would likely limit the amount of bed lowering that occurs. Although degradation has historically occurred from the confluence of the Jemez River to Bernalillo, this subreach would be close to equilibrium, due primarily to the increased sediment input from the Jemez River with the October 2001 elimination of the sediment pool in Jemez River. From Bernalillo to San Acacia would be slightly aggradational under this alternative. From San Acacia to the north boundary of Bosque del Apache National Wildlife Refuge (NWR), the channel would continue to be degradational, and the magnitude of the sediment imbalance would actually increase compared to recent historic conditions. From Bosque del Apache NWR to San Marcial would continue to aggrade with the late-1990s bed topography, but the recent base level lowering of the pool elevations in Elephant Butte Reservoir and construction of the Elephant Butte Pilot Channel are likely to result in a degradational trend in this reach, at least until the Elephant Butte pool level increases back to its historic higher levels.

Geomorphologic changes between alternatives were not significant. Except for the river channel below the San Acacia Diversion Dam, the computed change in bed elevation for the action alternatives would be nearly identical to the No Action Alternative. Very slight changes in the San Acacia Section river channel elevation were observed from the diversion dam to river mile 78. Aggradation in this reach ranged between 0.01 and 0.03 feet for the action alternatives. Below river mile 78, the computed lowering in bed elevation was 0.01 feet or less under all action alternatives. These minor changes in bed elevation should be viewed only in a relative sense because the changes would not occur uniformly in time or space through the reach, nor would they continue indefinitely as the channel geometry, gradient, and bed material adjust toward a state of equilibrium with the upstream supply. Changes below San Acacia were associated with the amount of diversion to the LFCC.

Sources of Uncertainty and Data Gaps

Most of the sources of uncertainty in the analysis of flow, storage, and geomorphology are related to availability of and confidence in gage, elevation, and other input data. Due to the 40-year planning horizon, computer modeling resources were constrained in their ability to perform multiple model runs. Thus, the particular 40-year inflow sequence may limit the degree of changes observed – especially when considering possible reservoir filling and emptying sequences. For example, the use of 2001 reservoir conditions coupled with the 40-year inflow sequence meant that the Elephant Butte/Caballo Reservoir flood control protocols were not invoked and impacts to the Southern Section were not considered. Due to the propagation of error along the river system, there is at least 10 percent uncertainty in model results increasing with downstream distance from Albuquerque.

Sensitivity analyses for the range of LFCC diversions under the No Action Alternative were performed as an adjunct to the primary alternative scenarios. In some cases, direct comparisons for the varying LFCC diversions under each alternative in the San Acacia section were not possible and qualitative estimates of impact substitute for quantitative analyses.

4.4.1.5 Summary/Comparison by Alternative

River flow and water movement throughout the Rio Chama and upper Rio Grande is constrained by the management of water in existing facilities under existing authorities and physical channel capacities. Differences between alternatives are subtle and may often be masked by gage error. Changes in operations typically have the greatest impacts to the river sections immediately in or downstream of the proposed change.

Along the Rio Chama, changes in storage using waivers at Heron Dam and storage of native conservation water in Abiquiu result in slight variations in daily and monthly flows. Alternatives B-3 and E-3 offer the greatest opportunity to store native Rio Grande water in Abiquiu Reservoir. Alternatives I-3 and E-3 offer slightly lesser advantages in native conservation storage. Alternatives I-2 and I-1 were constrained in their abilities to store water and offer intermediate storage up to the capacities of 75,000 and 25,000 AFY. Under the No Action Alternative, conservation water would not be stored. Under extreme circumstances and upon State request, native water can be stored and carried over only after obtaining expensive and cumbersome emergency deviations and permits.

No changes in operations are proposed on the Rio Grande above the confluence with the Rio Chama. Below the confluence, there are no significant changes to daily flows at Otowi under any of the alternatives; and all alternatives except I-1 show improvements in 75th percentile flows. Alternatives B-3 and I-3 also show improved median flows.

On the main stem of the Rio Grande near Albuquerque, Alternatives B-3 and E-3 (with increased channel capacity below Cochiti) show improved maximum and 75th percentile flows. Alternatives D-3 and I-3 also show greater 75th percentile flows, presumably due to releases in upstream storage. There were no significant changes in median or low flows among the other alternatives.

Flows in the San Acacia Section are influenced primarily by diversion to the LFCC and to a lesser extent by changes in channel capacity below Cochiti. Under the No Action Alternative when hydrology permits, river flows are maintained up to 250 cfs prior to diversion into the LFCC. The 2,000 cfs operation has the potential to divert over 100 percent of the river flow at San Acacia. Under the action alternatives with a 250 cfs bypass assumed in URGWOM, only 49 percent of the total flow is actually diverted by the model. By comparison, the 1,000 cfs flow diverts 47 percent and the 500 cfs flow diverts 37 percent of the total river flow. The San Acacia gage data for the No Action Alternative under various diversions to the LFCC show proportional decreases in river flows at the daily flow and 75th percentiles. Median and low flows converge quickly with diversion. The full 2,000 cfs capacity is used only 4 percent of the time; the 1,000 cfs capacity is used only 13 percent of the time; and the 500 cfs capacity is used 34 percent of the time over the 40-year period.

All alternatives result in higher median and average inflows to Elephant Butte Reservoir, as compared to No Action. Alternatives B-3 and E-3 provide the highest daily and 75th percentile flows. Alternatives I-1 and I-2 show reductions in daily flows when compared to No Action, but sustain higher mean and median flows over the 40-year period. Overall, Alternatives B-3 and E-3 deliver the most water to Elephant Butte Reservoir due to increased channel capacities below Cochiti Dam. The next highest ranked alternatives for managing water operations are Alternatives D-3 and I-3, offering comparable median and average flows as compared to B-3 and E-3. Alternatives I-2 and I-1 transmit lesser amounts of water, with No Action delivering the least water to Elephant Butte Reservoir.

Impacts to flows below Elephant Butte Reservoir were not considered as flood control protocols were not invoked during the 40-year planning period.

Geomorphologic impacts were considered insignificant as none of the changes exceeded a 10 percent departure from No Action. Sediment volumes, aggradation/degradation changes, and changes in bank energy indices were all similar to No Action, suggesting that changes in sediment volume and water flow among alternatives were not of sufficient magnitude to induce substantial changes in channel morphology.

Water flow in the upper Rio Grande basin is tightly constrained within the limits of current authorities and regulations. Performance measures for water operations flexibility and sediment management are summarized in **Table 4-3**.

The rank order of preference among alternatives after evaluating hydrologic and geomorphologic impacts is as follows: I-3, E-3, B-3, I-2, I-1, No Action, and D-3.

4.4.1.6 Mitigation Measures

Impacts for hydrologic effects requiring possible mitigation could include the occasional need for higher channel-forming flows and release of upstream storage for the benefit of New Mexico Compact deliveries and endangered species. Alternatives providing upstream storage of native conservation water allow the best potential for mitigating impacts to other resources. Geomorphologic characteristics were not significantly impacted by proposed changes in water operations, thus no mitigation measures were proposed.

Table 4-3. Operating Flexibility Performance Measures & Results

Parameter	Measure	Units	No Action LFCC-0 cfs	B-3	D-3	E-3	I-1	I-2	I-3
OPERATIONAL FLEXIBILITY									
Conservation Storage in Abiquiu	July 1 Median Storage (20 of 40 years)	AF	0	129,400	115,600	116,800	19,130	73,300	118,800
	# of Years Storage Occurs	Years	0	19	20	20	17	19	20
	SCORE		**0%**	**98%**	**95%**	**95%**	**50%**	**76%**	**96%**
Maximizes Peak Discharge	75th percentile Chamita Gage	cfs	585	616	601	607	640	589	607
	75th percentile Otowi Gage	cfs	1,533	1,704	1,654	1,671	1,529	1,611	1,674
	75th percentile Albuquerque Gage	cfs	1,134	1,389	1,289	1,331	1,150	1,246	1,331
	75th percentile San Acacia Gage*	cfs	1,210; 710; 250; 250	250	250	250	724	414	250
	SCORE		**83%**	**90%**	**87%**	**88%**	**85%**	**100%**	**88%**
Maximizes Sediment Transport	Total Sediment Volume	AF	993	753	765	759	869	814	760
	SCORE		**100%**	**76%**	**77%**	**76%**	**87%**	**82%**	**77%**
Supports Winter Flows (Dec-Feb)	Chamita Gage – median winter flow	cfs	214	234	220	224	221	218	222
	Otowi Gage – median winter flow	cfs	830	894	845	847	840	855	847
	Albuquerque Gage – median winter flow	cfs	799	847	823	826	813	820	826
	San Acacia Gage – median winter flow*	cfs	979; 488; 250; 250	250	250	250	491	250	250
	SCORE		**94%**	**100%**	**96%**	**97%**	**96%**	**96%**	**97%**
Stable Reservoir Levels	Heron – 75%/25% Elevation Fluctuation	Ft	54	56	55	54	54	54	54
	El Vado – 75%/25% Elevation Fluctuation	Ft	42	44	42	43	43	43	43
	Abiquiu – 75%/25% Elevation Fluctuation	Ft	21	31	30	30	18	25	30
	Cochiti – 75%/25% Elevation Fluctuation	Ft	1.8	1.7	1.7	1.8	1.8	1.8	1.9
	Elephant Butte – 75%/25% Storage Fluctuation	AF	310,028	324,540	321,735	321,193	338,395	342,669	320,581
	Caballo – 75%/25% Storage Fluctuation	AF	8,405	7,437	7,564	7,565	8,081	7,751	7,559
	SCORE		**90%**	**98%**	**96%**	**97%**	**88%**	**93%**	**98%**
Supports Recreation – Summer Rafting	April 1 – Sept 30, Chamita Gage >500 cfs	Days	132	122	122	119	126	122	119
	SCORE		**100%**	**92%**	**92%**	**90%**	**95%**	**92%**	**90%**
SEDIMENT MANAGEMENT									
Sediment Volume	Sediment Supply – Central	AF	409	401	401	402	407	403	399
	Sediment Supply – San Acacia**	AF	584	352	365	357	462	412	361

Parameter	Measure	Units	No Action LFCC-0 cfs	B-3	D-3	E-3	I-1	I-2	I-3
	Sediment Capacity – Central	AF	386	372	375	376	384	378	380
	Sediment Capacity – San Acacia**	AF	542	314	329	320	436	381	325
	SCORE		**100%**	**79%**	**80%**	**80%**	**89%**	**84%**	**80%**
Aggradation/ Degradation Trends positive = aggradation	Ag/Deg Volume – Central	AF	23	27	26	26	23	25	26
	Ag/Deg Volume – San Acacia**	AF	42	38	36	37	26	30	36
	SCORE		**93%**	**96%**	**91%**	**94%**	**75%**	**83%**	**93%**
Bank Energy Index positive = increased erosion negative = decreased erosion	Chama	Percent	0	2.17	2.58	-0.23	-0.23	-0.55	-0.21
	Central	Percent	0	-1.28	-0.95	-1.06	-0.12	-0.56	-1.23
	San Acacia – North	Percent	0	0.24	0.22	0.1	0.22	0.31	0.21
	San Acacia – South**	Percent	0	-58.1	-56.4	-57.4	-26.6	-42.8	-56.6
	SCORE		**99%**	**90%**	**90%**	**89%**	**95%**	**92%**	**89%**

Notes: * Range of flows under No Action at LFCC Diversions of: 0, 500, 1,000, and 2,000 cfs.
** Range of flows under No Action LFCC Diversions not evaluated – comparisons reflect action of LFCC, not difference between alternatives at same level of No Action diversion.

4.4.2 Biological Resources

4.4.2.1 Aquatic Habitat

Issues

Both riverine and reservoir aquatic impacts were evaluated in the analysis of alternatives. Alternatives that alter the magnitude, variability, and duration of flow were assumed to have the potential to change the availability of suitable riverine fish habitat, the timing and magnitude of spawning peaks, and the timing and degree of potential intermittencies. Alternatives that change upstream storage and affect reservoir elevations were assumed to have potential impacts on littoral (shoreline) habitat, reservoir exchange rates, and reservoir fish habitat.

The Rio Grande silvery minnow (RGSM) is the only threatened and endangered species identified in the riverine habitat. Impacts to RGSM habitat are briefly evaluated here and are discussed in greater detail in Section 3.2.4.1.

General Conclusions

Possible changes in reservoir storage included modifying waiver dates in Heron Reservoir and increasing the amount of native conservation storage in Abiquiu Reservoir.

Heron Waivers: Changes in waiver dates have the potential to modify spring and summer reservoir storage; however, analysis for Heron Reservoir was limited to an evaluation of water elevation stability and exchange rates. Statistical analysis of Heron Reservoir daily storage did not reveal any significant changes among the alternatives. Alternatives B-3 and D-3 appeared to support lower exchange rates with possible impacts to reservoir fisheries. Alternatives I-3, I-1, I-2, and I-3 did not show significant changes.

Native Conservation Storage in Abiquiu Reservoir: Changes in storage affect reservoir elevation, rates of water exchange, and littoral habitat availability. Alternatives B-3, D-3, E-3, and I-3 maximize storage, with median reservoir storage typically greater than 90,000 AF. However, these alternatives experience lower rates of water exchange than other alternatives, with possible negative impacts to reservoir fisheries. Littoral habitat availability is increased under Alternatives I-3 and D-3, counterbalancing lower exchange rates. Alternatives with lesser storage, I-1 and I-2, provided increased littoral habitat, but low exchange rates. Downstream impacts to fisheries in Cochiti Reservoir showed dampened responses. Median storage in Cochiti is not affected by the alternatives; however, changes in Cochiti storage are maximized when there is less storage available in Abiquiu. Thus, Alternatives I-1 and I-2 have the potential for higher reservoir elevations than other alternatives. Also, alternatives with increased channel capacities below Cochiti (B-3 and D-3) offer the most stable reservoir levels as flood waters can be evacuated more quickly with higher channel capacities. There were no noticeable changes in reservoir exchange rates among alternatives. Changes in storage and channel capacity also modified river flows in some segments of the river. The greatest magnitude of change to flow occurs along the Rio Chama, where all changes in storage occur, than in the Central and San Acacia Sections, where changes in channel capacity and diversion to the LFCC affect flows.

Fish habitat was generally not significantly affected (less than 2 percent) until the San Acacia Section. Progressive diversion to the LFCC resulted in loss of fish habitat. Diversion to the LFCC at 1,500 cfs resulted in the greatest impacts, with habitat losses ranging from 19 (RGSM) to 49 percent (longnose dace). Alternatives were compared to the No Action Alternative with the corresponding level of diversion to the LFCC. Alternatives B-3, D-3, E-3, and I-3, had 6 to 27 percent habitat area losses observed when compared to No Action diverting up to 2,000 cfs to the LFCC. No major changes in fish habitat over comparable No Action Alternative diversions to the LFCC were observed under Alternatives I-1 and I-2 in comparison to No Action at 500 and 1,000 cfs diversion, respectively.

Impact Indicators

Both riverine and reservoir impacts were assessed in the evaluation of alternatives. Indicators are identified below.

Riverine	Reservoir
Fish habitat area	Reservoir elevation stability
Duration of overbank flooding	Littoral habitat area
Area of overbank flooding	Water exchange rate
Average low flow days	
Average peak flow magnitude and duration	
Low flow augmentation capability	

Methods of Analysis

Riverine impacts were evaluated by considering periods of high and low flows, periods of intermittent flows, area and duration of overbank flooding, and suitable aquatic fish habitat. The potential for supplementing flows using native conservation storage was also assessed. Flows were evaluated at key gages based on URGWOM modeling. The area and duration of overbank flooding was estimated based on analysis of FLO-2D outputs for each alternative. Estimates of fish habitat area by indicator species and life stage were obtained as output from the aquatic habitat model. Indicator species selected for fish habitat analyses included the RGSM, longnose dace, flathead chub, carpsucker, and channel catfish. Appendix L provides information concerning ecosystem resource analyses. Additional information concerning the FLO-2D and aquatic habitat models is provided in Appendices J and K.

Impacts to reservoir habitats were analyzed considering the net reservoir elevation rate of change, the area of littoral habitat available, and the reservoir exchange rate. Habitat stability (measured by rate of change in reservoir elevation), is important in spring months to promote successful reproduction of fish species that spawn in submerged vegetation in the shoreline habitats. Values closest to zero represent reservoir stability. The amount of shoreline habitat measures the availability of spawning, nursery, and foraging habitat crucial to the reproduction of reservoir fish species. Littoral habitat data were available only for Abiquiu Reservoir. For other reservoirs, shoreline habitat availability was estimated using the three-dimensional shape of each reservoir and reservoir elevation changes predicted under each alternative. The number of days available in ten-foot elevation increments was then calculated. High values of littoral habitat are the most desirable. The reservoir exchange rate considers the turnover of water in each reservoir as a measure of fishery productivity and is calculated by dividing the reservoir volume by the average annual discharge. Low exchange rates are generally associated with higher productivity and better fisheries support.

Thresholds for Significance

Propagation of error and uncertainty is expected with the use of modeling tools that build upon data received from river gages and elevation measures. Starting with an initial 5 percent gage error, using a series of models including the URGWOM planning model, spatial analysis of flow and habitat using RMA-2 and the Aquatic Habitat Model, the starting point for identifying significant changes is expected to be at least 10 percent deviation from No Action.

Discussion of Results

The No Action Alternative with zero diversions to the LFCC would offer the highest potential for preserving aquatic habitats in the system. The No Action Alternative would best preserve riverine fish diversity, receiving maximum scores on all parameters with the exception of brown trout habitat, where the alternative ranks third overall. With zero diversions to the LFCC, the No Action Alternative would best preserve hydrology supporting aquatic habitats in the San Acacia Section, with slightly lesser performance in the Rio Chama and Central Sections due to reduced overbank flooding acres and durations. The No Action Alternative would provide mid-ranked reservoir stability and reservoir exchange rates, ranking fourth among alternatives for the reservoir parameters evaluated. With zero diversions to the LFCC, it ranks third overall among the alternatives evaluated for riverine and reservoir aquatic resources.

All alternatives were compared to the No Action Alternative. No significant changes in usable fish habitat were identified in the Rio Chama and Central Sections (±2 percent). Detailed analysis can be found in Appendix L.

The Rio Grande silvery minnow (RSGM) is extirpated from Rio Chama. Alternative B-3 would result in a reduction of habitat in the Rio Chama Section for all other species. Brown trout habitat would be reduced under Alternatives B-3, D-3, E-3, and I-3; would not change under Alternative I-2; and would increase slightly under Alternative I-1. Habitat for longnose dace, flathead chub, carpsucker, and channel catfish would increase under all alternatives except Alternative B-3. The projected changes in riverine habitat parameters, including RGSM habitat area, are shown in **Table 4-4**.

Table 4-4. RGSM and Riverine Habitat Change by Alternative

Alternative	RGSM Habitat Area (sq. feet)	Duration of Overbank Flooding (avg. days/year)	Area of Overbank Flooding (acres)	Average Number of Days of 0 cfs	Average Number of Days <100 cfs	Average High Flow Magnitude (cfs)	Average High Flow Duration (days/year)
RIO CHAMA SECTION							
No Action	55,030	2	477,530	0	9	2,900	54
B-3	51,020	29	137,600	0	9	2,520	53
D-3	53,200	28	489,700	0	10	2,740	47
E-3	52,790	26	323,750	0	9	2,670	49
I-1	53,520	28	331,840	0	9	1,920	53
I-2	52,730	31	396,600	0	9	2,790	48
I-3	52,910	37	477,530	0	10	2,670	49
CENTRAL SECTION							
No Action	1,224,030	15	1,545,900	15	33	3,970	48
B-3	1,200,200	11	2,731,600	15	32	3,850	44
D-3	1,206,700	13	1,663,300	16	33	3,770	44
E-3	1,204,040	9	2,938,000	16	33	4,010	42
I-1	1,217,400	12	1,424,500	16	33	4,050	47
I-2	1,204,600	13	1,598,500	16	33	3,870	45
I-3	1,203,100	16	1,800,900	16	33	3,700	46
SAN ACACIA SECTION							
No Action – 0 cfs	511,470	33	8,789,800	0	99	3,580	39
No Action – 500 cfs	460,500	—	7,119,700	69	214	3,205	34
No Action – 1,000 cfs	422,700	—	5,361,760	69	214	2,710	29
No Action – 1,500 cfs	412,570	—	--	69	—	—	—
No Action – 2,000 cfs	434,970	—	2,461,140	69	214	2,400	26
B-3	406,650	10	2,679,000	—	108	2,010	26
D-3	405,630	11	2,375,500	—	110	1,920	29
E-3	406,900	8	2,606,200	—	109	2,150	26
I-1	458,600	16	4,386,800	—	106	2,710	34
I-2	425,150	27	7,952,100	—	109	2,700	29
I-3	405,730	29	8,251,500	—	110	1,860	28

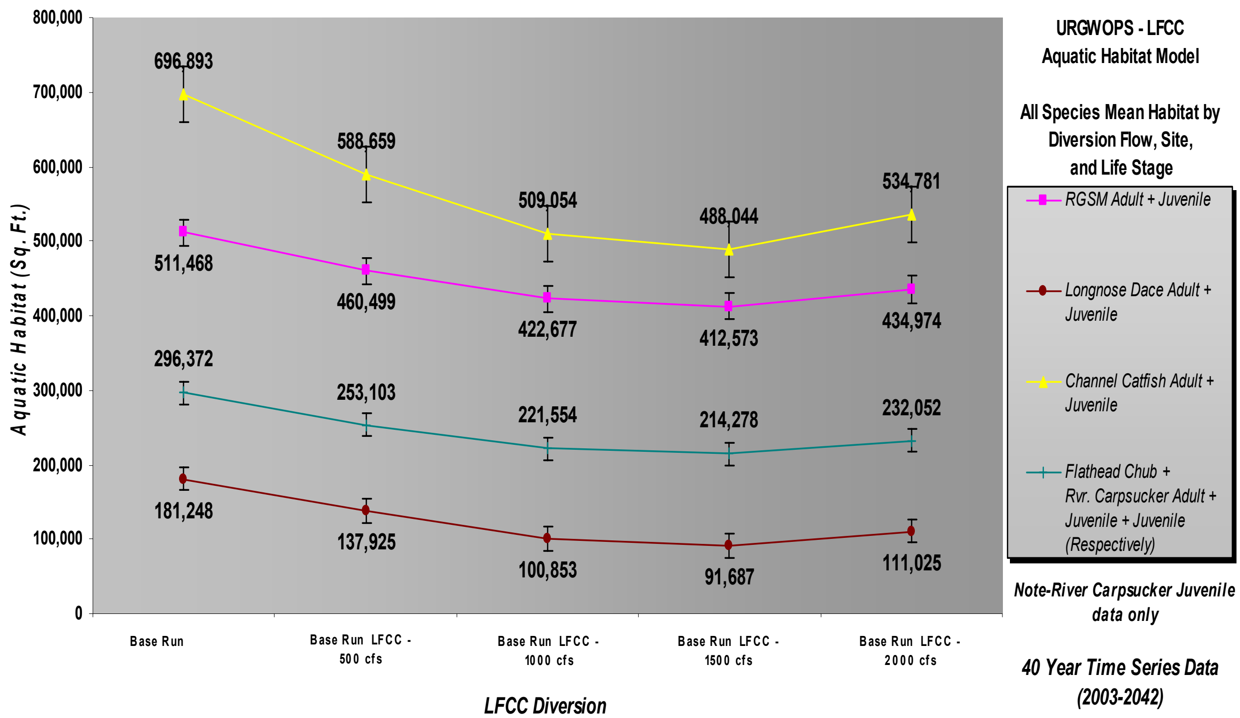
Note: — No Data Available

Table 4-5 summarizes the effects on aquatic habitats in the San Acacia Section under each action alternative, compared to the No Action Alternative. Available aquatic habitat for the indicator fish species is maximized under zero diversions to the LFCC. Habitat decreases with 1,000 to 1,500 cfs diversions to the LFCC, while improvements are observed with diversions of 2,000 cfs. The longnose dace has the greatest reductions in habitat with diversion to the LFCC. **Figure 4-13** shows the impact of diversion to the LFCC on longnose dace at several life stages. A significant decrease in adult and juvenile habitats for longnose dace is observed at the Bosque del Apache National Wildlife Refuge (NWR) site.

1 **Table 4-5. Significant Change in Usable Fish Habitat in the San Acacia Section**

Action Alternative	Change of Habitat Compared to the No Action Alternative with Comparable Diversion to the LFCC			
	RGSM	Longnose Dace	Chub/ Carpsucker	Channel Catfish
B-3	-6%	-27%	-10%	-10%
D-3	-7%	-22%	-10%	-10%
E-3	-6%	-21%	-10%	-10%
I-1	0%	0%	0%	0%
I-2	+1%	+5%	+1%	+2%
I-3	-7%	-21%	-10%	-10%

2



3 **Figure 4-13. Longnose Dace Habitat Impacts with LFCC Diversion under No Action**

One of the drawbacks to the No Action Alternative is that it would not provide any upstream s water that might be used to augment flows for ecosystem needs. When stored water was avail emergency exceptions were made in the past on a case-by-case basis to accommodate endang needs in times of drought without considering system-wide implications. However, the process depends on identifying water rights holders in possession of sufficient water in storage and a willingness to relinquish that water, typically using a short-term lease. But these emergency exceptions and deviations are difficult to negotiate, are time-consuming and expensive to implement, and provide limited options for long-term ecosystem management to improve the status of all species.

The ability to provide low flow augmentation was also considered in the analysis of alternatives (**Figure 4-14**). Supplemental flows could help mitigate the effects of zero and low flow days on riverine habitat and fish communities. Alternatives D-3, E-3, and I-3 could mitigate low flow days in the Central Section, but stored volumes of water are approximately 10 days short to provide sufficient water to supplement flows in the San Acacia Section. Alternative I-2 would satisfy needs in the Central Section, but would be 48 days short in the San Acacia Section. Alternative I-1 is short on water for 16 days in the Central Section and 100 days in the San Acacia Section. Only Alternative B-3 provided sufficient water to surpass the number of predicted days less than 100 cfs at both Central and San Acacia sections. No water is available for augmentation under the No Action Alternative, except by emergency deviations.

No impacts were projected from water operations alternatives for Platoro and Jemez Canyon Reservoirs. Elephant Butte Reservoir and Caballo Reservoir were not explicitly evaluated, as this EIS considers only impacts from flood control operations and not water supply. Impacts to El Vado Reservoir were not addressed due to ongoing litigation.

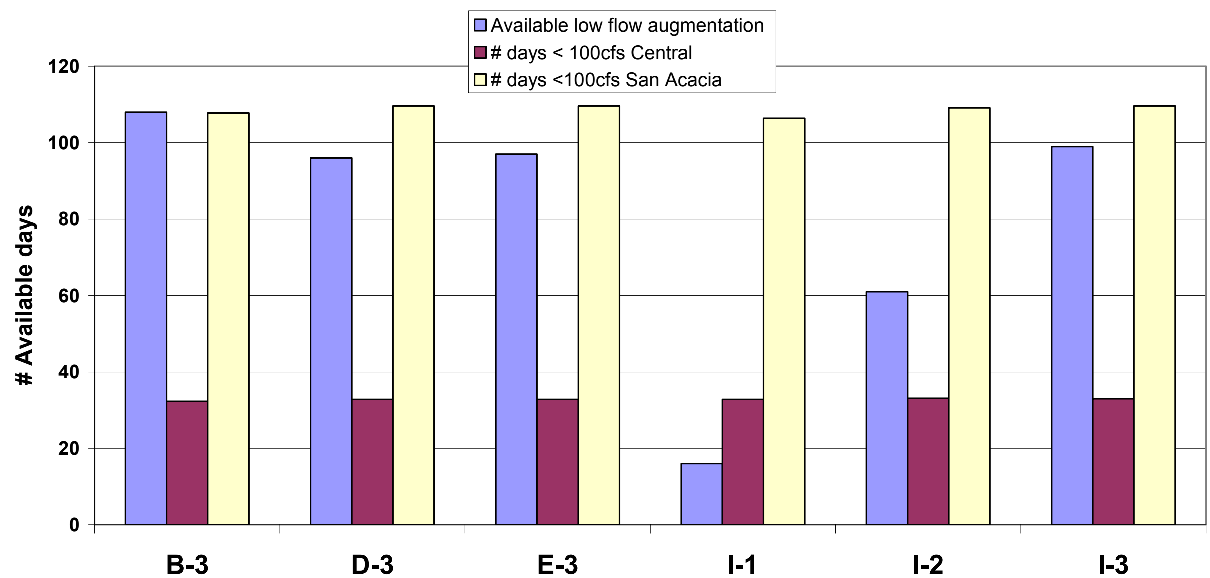


Figure 4-14. Low Flow Augmentation by Alternative

Reservoir fisheries impact analyses for Heron, Abiquiu, and Cochiti Reservoirs are summarized in **Table 4-6**. At Heron Reservoir, elevation rates of change are most stable with the lowest exchange rates observed under Alternatives B-3 and D-3. All other alternatives are similar to No Action. Littoral habitat availability in Abiquiu Reservoir improves under all action alternatives, while exchange rates suffer slightly. At Cochiti Reservoir, reservoir stability improves under all action alternatives except I-1; exchange rates are less favorable under Alternatives I-1, I-2, and I-3. In summary, Alternatives B-3, D-3, and E-3 offer similar reservoir conditions as compared to No Action. Action Alternatives I-1, I-2, and I-3 are slightly less favorable than No Action in reservoir fisheries support, primarily due to increases in reservoir exchange rates at Abiquiu and Cochiti Reservoirs.

Table 4-6. Summary of Reservoir Fisheries Impacts by Alternative

Parameter	Units	Desired Condition	No Action	B-3	D-3	E-3	I-1	I-2	I-3	Comments
HERON RESERVOIR										
Net Reservoir Elevation Range of Change	ft/week	Zero	-0.001	-0.001	-0.001	-0.012	-0.009	-0.011	-0.012	B-3 and D-3 are most favorable
Area of Littoral Habitat	Acre-days	Maximum	NA	NA	NA	NA	NA	NA	NA	No data available
Reservoir Exchange Rate	AFY	Minimum	0.796	0.779	0.788	0.798	0.796	0.798	0.798	No significant change
ABIQUIU RESERVOIR										
Net Reservoir Elevation Range of Change	ft/week	Zero	0.029	0.228	0.342	0.326	0.086	0.262	0.337	No Action & I-3 are most favorable
Area of Littoral Habitat	Acre-days	Maximum	42,840	42,840	54,612	48,756	54,612	48,756	48,756	D-3 and I-1 are most favorable
Reservoir Exchange Rate	AFY	Minimum	0.017	0.019	0.019	0.019	0.272	0.274	0.275	I-1, I-2, and I-3 are least favorable
COCHITI RESERVOIR										
Net Reservoir Elevation Range of Change	ft/week	Zero	0.13	0	0.081	-0.008	0.145	0.098	0.084	B-3 and D-3 are most favorable
Area of Littoral Habitat	Acre-days	Maximum	NA	NA	NA	NA	NA	NA	NA	No data available
Reservoir Exchange Rate	AFY	Minimum	0.007	0.007	0.007	0.007	0.117	0.117	0.117	I-1, I-2, and I-3 are least favorable

Sources of Uncertainty and Data Gaps

Sources of uncertainty and data gaps in the analysis of riverine and reservoir habitat include propagation of gage and URGWOM modeling error, understanding of desirable fish habitat conditions, model spatial sensitivity and further propagation of error across the Aquatic Habitat and FLO-2D models. The combined potential effects suggest that changes predicted by modeling would be significant if there is a greater than 10 percent departure from conditions predicted under No Action.

Summary/Comparison by Alternative: Aquatic Riverine and Reservoir Habitats

There were no significant changes in riverine fish habitat in the Rio Chama and Central Sections. The RGSM is considered extirpated in the Rio Chama Section and changes in habitat were less than 2 percent (about ½ acre) from No Action for the Central Section. However, any loss of habitat for the RGSM in the Rio Grande should be avoided because it could contribute to its extirpation in other areas of the river and confound future recovery efforts.

Significant changes in fish habitat were observed in the San Acacia Section and are, for the most part, related to diversions to the LFCC. The performance of each alternative in the San Acacia Section is referenced against the appropriate level of LFCC diversion under the No Action Alternative. Under Alternatives I-1 and I-2, small increases (1 to 5 percent, respectively, were observed) in fish habitat for all species in the San Acacia Section. Habitat losses in the San Acacia Section would be significant for all species under Alternatives B-3, D-3, E-3, and I-3. A 6 to 7 percent reduction in total RGSM habitat (about 0.67 acres) is projected under Alternatives B-3, D-3, E-3, and I-3. Longnose dace habitat would be reduced by over 20 percent, while chub/carpsucker and catfish habitat would be reduced by almost 10 percent. Habitat losses for all species may be highest in the San Acacia Section due to many factors, including diversion to the LFCC, higher channel velocities for alternatives with increased channel capacities in the Central Section, and native conservation storage in upstream reservoirs.

In contrast to the results obtained for riverine habitat analyses, Alternatives B-3, D-3, and E-3 provided reservoir fisheries support similar to that observed under No Action. Alternatives I-1, I-2, and I-3 had significant decreases in reservoir fisheries support, primarily related to lower reservoir exchange rates coupled with changing reservoir elevations.

Overall, aquatic habitats were best supported by the No Action Alternative, with zero diversions to the LFCC. Riverine fish habitat area in the San Acacia Section was negatively affected under No Action by LFCC diversions of 1,000 and 1,500 cfs. The aquatic habitat ranking order of the action alternatives is as follows: I-2, I-1, I-3, D-3, B-3, and E-3. However, there is only a three percentage point difference in overall weighted resource performance measures among the action alternatives other than No Action. **Figure 4-15** provides a summary of alternative performance relative to aquatic habitat criteria.

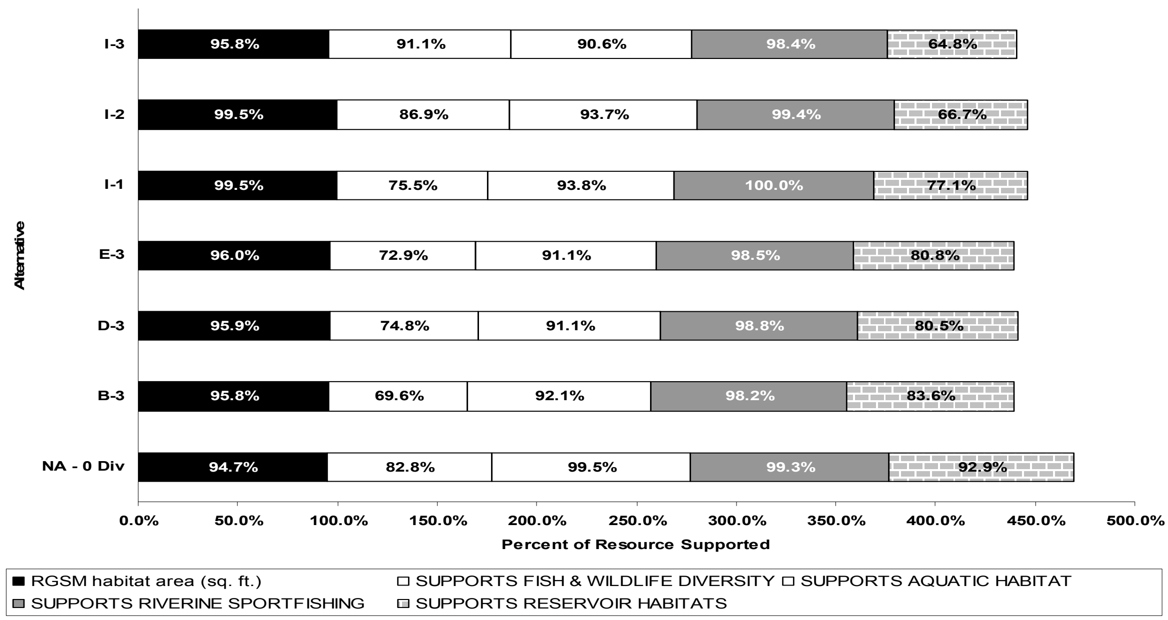


Figure 4-15. Aquatic Habitat Resources Supported by Alternative

Mitigation Measures

Mitigation measures for alternatives with projected loss of critical habitat would include support of habitat restoration activities in the sections affected. Alternatively, the specific use of stored native conservation water with carryover storage agreements could be negotiated to allow for water flows that foster the development of additional habitat in years where low peak flows and/or periods of intermittency would not adequately support species.

Figure 4-16 illustrates possible aquatic habitat gains predicted when conservation storage flows are released to meet specific flow targets (100 or 200 cfs) at the Central and San Acacia gages. Thus, some of the potential habitat lost under active diversion to the LFCC could be mitigated by releases of conservation storage water, resulting in additional habitat upstream of the LFCC diversion.

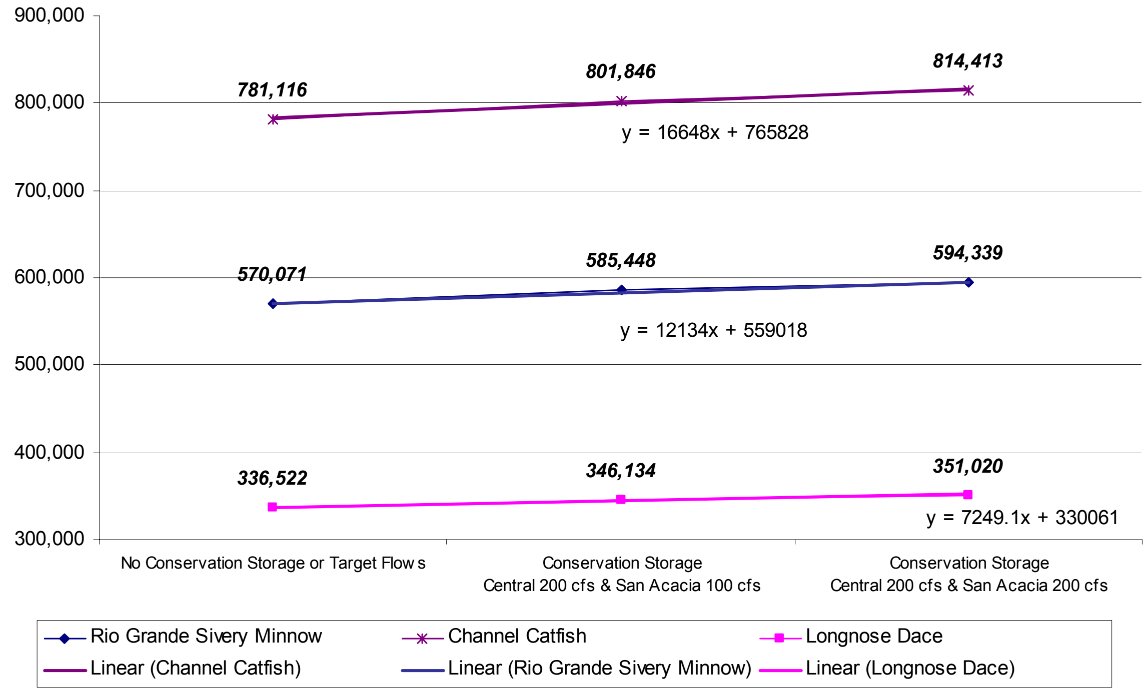


Figure 4-16. Fish Habitat Area Gained Using Native Conservation Storage Water to Meet Flow Targets

Figure 4-17 is a rose diagram depicting the potential to use the Abiquiu native conservation storage available under Alternative B-3. The figure shows the effects of using an annual storage allotment to supplement flows (either 40,000 or 75,000 AF) combined with a year-to-year carryover provision. The year-to-year carryover provisions evaluated allow either 25 or 50 percent of the conservation water remaining at the end of the calendar year to be held in the reservoir for use the following season. In each case (4 options), it was assumed that the full target allotment was used in a given year and that the appropriate fraction of carryover water was left in storage for the following year, subject to storage limits of the reservoir, flood control requirements, and higher priority needs for San Juan-Chama Project water storage. Negotiation of carryover storage provisions allows the capability to meet flow targets in several successive years, thereby offering a possible buffer during short-term droughts. This is best illustrated by examining water availability from years 17 to 20 and years 37 through 40. The lower amount of reserved water storage combined with the ability to carryover 50 percent of the unused portion (Alternative B-3, option C in Figure 4-18) provides the greatest opportunities to buffer a dry period of several years. While most of the options in the following rose diagram have the same amounts of native water stored in each year, evidenced by the years when the lines overlay each other, option C (green line) is shown to have a few more years at higher storage levels, encompassing a larger area in the diagram.

Using less than the projected stored water provides slightly more water for carryover to the next year. It is not only the ability to seasonally store water, but the negotiation of carryover provisions for this stored water that allows optimal flexibility to meet ecosystem needs.

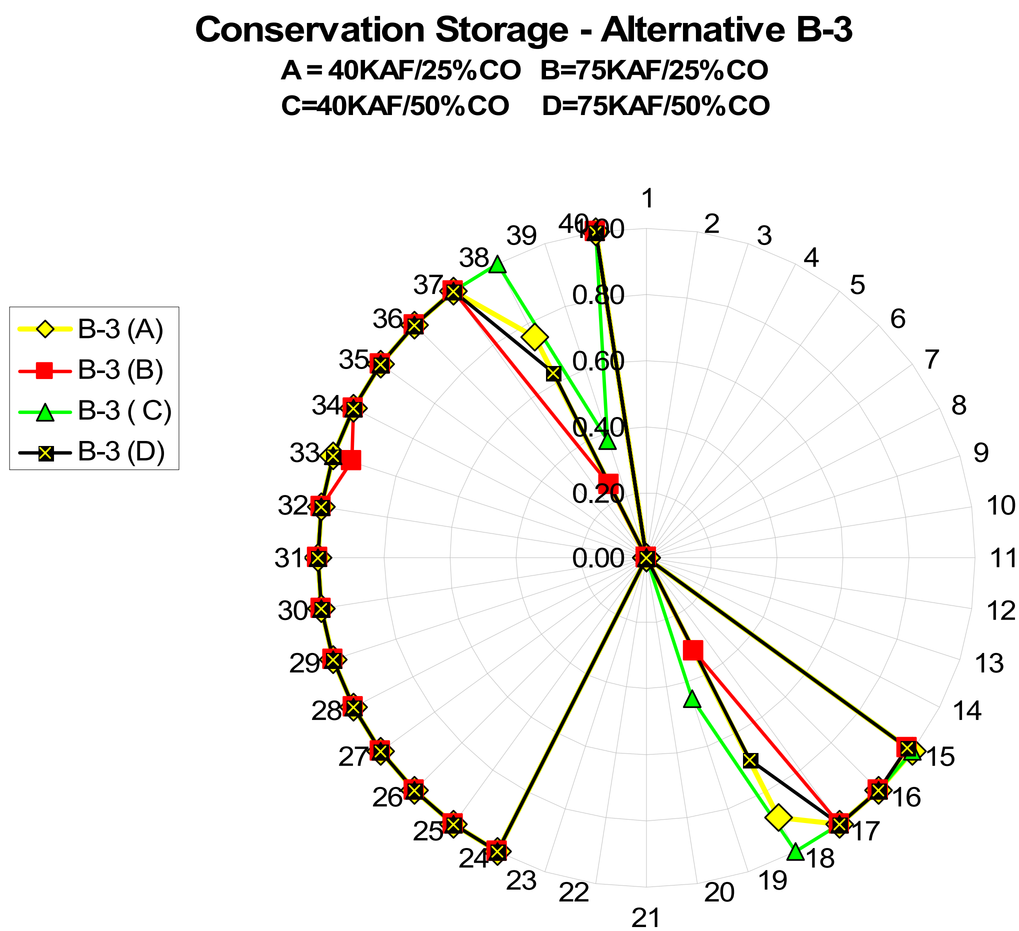


Figure 4-17. Using Native Conservation Storage to Meet Flow Targets

4.4.2.2 Riparian Habitat

Issues

Riparian habitats include the soils, vegetation, and associated wildlife that border waterways, including the open sand bars along the main river channels. Healthy riparian zones include a diversity of plants and structural types, as well as a variety of native and non-native species. Impacts on riparian habitat related to changes in water operations are generally indirect and long-term. Periodic overbank flooding is needed to maintain the health of established native plant communities; to scour away existing vegetation and create new seedbeds for the regeneration of young vegetation; and reduce susceptibility to fire, infestation of non-native species, and disease. The timing, duration, and magnitude of peak flood flows are also critical to maintaining desired habitats and wildlife diversity. High hydrologic variability often correlates to habitat and species diversity.

Physiography and geomorphology also play a role in shaping riparian habitats by constraining bed mobility and opportunities for overbank flooding. For example, the Rio Chama Section is characterized by a steep canyon with a sharp gradient and narrow floodplain. This section has high structural diversity characterized by predominantly native vegetation of mixed age and species. In contrast, the Central Section is a warm-water reach with a riparian vegetation corridor known as the “bosque” supporting a mixture of non-native and native species. Levees and irrigation further constrain the corridor and structural diversity is low. The San Acacia Section is relatively unconstrained by levees, with the LFCC comprising a western boundary. This mobile sand bed river has historically been subject to aggradation in the San Acacia Section. It is dominated by saltcedar, mixed native and non-native vegetation, and contains relatively large areas of young to intermediate-aged riparian forests with high biological value.

General Conclusions

Riparian resources are best supported by alternatives that provide increased opportunities for overbank flooding that sustain and regenerate desirable habitat. Opportunities for overbank flooding are available either by the operational constraints on releases combined with natural spring runoff, or by augmentation of spring runoff using conservation storage.

The San Acacia Section contains the greatest acreage of riparian habitat. However, habitat improvements are also possible in the Central and Rio Chama Sections. Thus, care was used in the analysis to weigh riparian impacts by section, rather than by total acres of impact. Higher channel capacities and lesser diversions to the LFCC offer higher river flow potentials, while intermediate diversions to the LFCC increased the level of groundwater support to wetland areas. Based on the analyses of impact indicators, Alternatives I-1, I-2, and No Action (with LFCC diversions up to 1,000 cfs) best support riparian resources. Of the remaining alternatives with 2,000 cfs diversions to the LFCC, the order of preference in riparian resources supported is as follows: E-3, D-3, I-3, and B-3.

Impact Indicators

Changes in water operations have the potential to affect riparian resources, but such impacts are typically indirect and long-term. Potential beneficial and adverse impacts to riparian resources were evaluated using the quantitative measures listed below.

- Acre-days of spring overbank flooding
- Percentile of inundation
- Frequency of overbank flooding
- High flow variability
- Mean annual maximum acres of overbank flooding
- Conservation storage capability
- Average annual acre-days of flooding by vegetation type
- Flow augmentation

Additional details on the derivation and use of these impact indicators is provided in Appendix L.

Methods of Analysis

The primary tools for estimating biological effects included the URGWOM planning model, Hink and Ohmart vegetation classification and mapping (1982 data and adapted methods applied in 2002-2003), and FLO-2D models generated for the Rio Grande and Rio Chama (Appendix J). The combined modeling and mapping efforts provided information for analysis, typically assuming that the operational maximum allowed under each alternative would be exercised. That is, if conservation storage was allowed up to 180,000 AF, then storage would be maximized when available. Similarly, if flows at San Acacia permit diversion to the LFCC, then diversion would be performed up to the allowed capacity of the LFCC. In many cases, hydrology and Compact constraints limit the ability to store and/or divert water, not the physical maxima available in the facilities.

The FLO-2D model of overbank inundation is most precise and accurate in the Rio Chama and Central sections. It is less reliable in predicting inundation in the San Acacia Section due to streambed instability. FLO-2D modeling was supplemented by Reclamation’s use of the Hydrologic Engineering Centers River

Analysis System (HEC-RAS) model for flows below the San Marcial gage to evaluate the portion of the San Acacia Section between the south boundary of Bosque del Apache NWR and the power lines at the full pool of Elephant Butte Reservoir. HEC-RAS data were merged with FLO-2D data and analyzed using Geographic Information System (GIS) to evaluate the effects of flooding greater than 0.5 foot.

Thresholds for Significance

As stated for other resources, minimum gage error in this system is 5 percent; propagation of error increases with successive layers of modeling and analysis. Thus, a minimum change of 10 percent was assumed to be the threshold for significant change, with the exception of analyses for threatened and endangered species, which are addressed in a separate section.

Discussion of Results of Analysis

Table 4-7 shows a comparison of the effects of the alternatives, by river section, on riparian habitat performance measures. Under the No Action Alternative, operations would continue largely unchanged, but with improved inter-agency coordination for flood control and delivery of water downstream. With no diversion into the LFCC, current operations would provide the best overall support for riparian resources compared with all the action alternatives. Current operations demonstrated support for existing wetlands, natural management areas, riparian fauna, and threatened and endangered species. However, despite overall support of riparian resources, adverse impacts would occur under the No Action Alternative, varying in degree by river section.

The action alternatives and the No Action Alternative test the potential effects of four sets of operational rules for the LFCC in the San Acacia Section. Each of the alternatives specifies a range of LFCC diversions up to maximum capacities. The ranges of LFCC diversions represented were as follows: 0-500 cfs; 0-1,000 cfs; and 0-2,000 cfs. Sensitivity analyses were also performed for the No Action Alternative modeling a range of intermediate diversions to the LFCC (0, 500, 1,000, 1,500, and 2,000 cfs diversions). In the San Acacia Section, there are only limited data available allowing direct comparison between No Action under the various levels of LFCC diversion and the corresponding alternatives with the appropriate level of LFCC diversion. Diversion to the LFCC has the greatest range of effects on acres inundated in the San Acacia Section. Under No Action, implementing the maximum LFCC diversion of 2,000 cfs leads to a 58 percent reduction of inundated acres compared to No Action with zero diversions.

In the Rio Chama Section, the No Action Alternative would provide less overbank flooding during the growing season to native vegetation types (i.e., mature cottonwood overstory and native vegetation of intermediate height classes), compared with the best-performing action alternatives. The long-term impact of decreased overbank flooding in these vegetation types would produce a general decrease in the mature cottonwood and willow vegetation in the Rio Chama Section.

Beneficial impacts to riparian vegetation would occur in the Central Section under Alternatives B-3 and E-3, both with higher channel capacities proposed below Cochiti Dam. The remaining alternatives (D-3, I-1, I-2, and I-3) perform similarly to the No Action Alternative. Since most facility operations remain unchanged in the Central Section for these alternatives, negative trends in the riparian ecosystem of the Central Section identified in Chapter 3, such as lack of recruitment of native vegetation and lack of sediment mobilization, would continue.

Table 4-7. Effects of Alternatives on Riparian Habitat Performance Measures

Performance Measure	Units	No Action				B-3	D-3	E-3	I-1	I-2	I-3
RIO CHAMA											
Mean Annual Maximum Acres Flooded	Acres	131				44	127	95	131	109	93
Mean Annual Acre-Days of Flooding	Acre-days	347				586	2,543	1,789	2,894	2,266	1,796
Frequency of Spring Flooding	Percent	43%				39%	39%	40%	43%	41%	40%
Days greater than 75th percentile flows	Days	1,830				1,513	1,470	1,499	1,782	1,625	1,499
Peak Flow Variability – Coefficient of Variation (CV)	CV	23				32	36	34	23	28	35
Mean July 1 Conservation Storage – Abiquiu Reservoir (AF)	AF	0				53,574	50,375	51,341	8,141	32,328	51,557
Peak Flow Augmentation Capability (rank)	Rank	7				1	4	3	6	5	3
CENTRAL SECTION											
Mean Annual Maximum Acres Flooded	Acres	382				675	411	726	445	395	352
Mean Annual Acre-Days of Flooding	Acre-days	11,089				12,350	11,072	12,774	11,989	10,792	10,018
Frequency of Spring Flooding	Percent	14%				14%	17%	11%	14%	16%	17%
Days greater than 75th percentile flows	Days	1,830				1,570	1,559	1,567	1,802	1,676	1,578
Peak Flow Variability – Coefficient of Variation (CV)	CV	47				57	51	58	48	49	51
SAN ACACIA SECTION *(LFCC Diversion in cfs)*		***0***	***500***	***1,000***	***2,000***	***2,000***	***2,000***	***2,000***	***500***	***1,000***	***2,000***
Mean Annual Maximum Acres Flooded	Acres	3,788	3,236	2,680	1,615	662	587	644	2,039	1,965	1,084
Mean Annual Acre-Days of Flooding	Acre-days	70,973	--	--	--	13,338	14,848	12,991	58,434	53,512	29,577
Frequency of Spring Flooding	Per-cent	53%	--	--	--	48%	48%	40%	53%	50%	50%
Days greater than 75th percentile flows	Days	1,830	1,830	1,830	1,830	2,074	2,166	2,166	1,830	1,891	2,166
Peak Flow Variability – Coefficient of Variation (CV)	CV	46	--	--	--	94.1	84.8	95.1	53.4	65	85.6

Without diversions to the LFCC, the No Action Alternative would provide the greatest amount of overbank flooding to the San Acacia Section, including wetland areas. Should the LFCC become operational, Reclamation could potentially divert up to 2,000 cfs, if in compliance with all pertinent Biological Opinion(s). Implementation of diversions would result in a reduction of overbank flooding, as shown in **Figure 4-18**. It is anticipated that long-term adverse effects would occur to riparian resources as a result of reduced levels of inundation. Both acres and duration of inundation decrease under the action alternatives, with a similar frequency of spring inundation for all alternatives except E-3. However, higher flows in the San Acacia Section are accommodated under Alternatives B-3, D-3, E-3, and I-3 providing greater hydrologic variability.

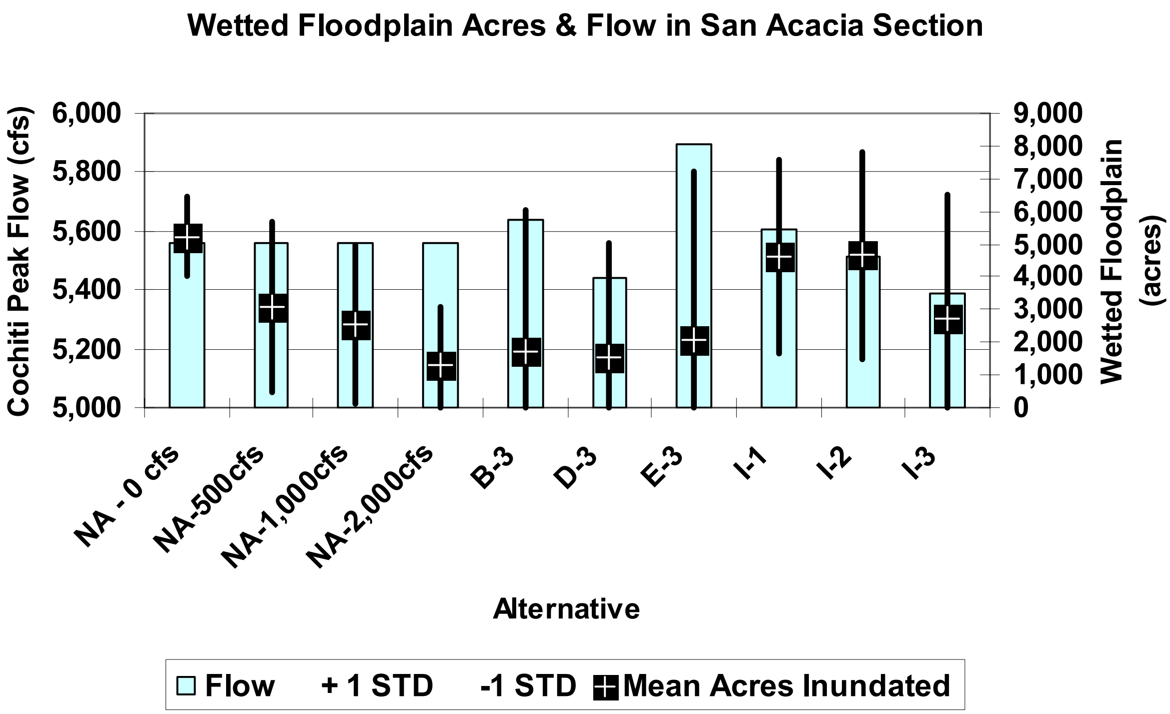


Figure 4-18. San Acacia Section Inundation vs. LFCC Diversion under No Action

As shown on Figure 4-18, progressive diversions to the LFCC under No Action result in decreases in the maximum, median, mean, and minimum wetted floodplain acres. Results suggest that Alternatives E-3 and I-3 provide higher levels of riparian support than No Action at 2,000 cfs. Alternatives B-3 and D-3 provide slightly reduced maximum acreages, medians, and means when compared to No Action at 2,000 cfs. Similarly, Alternatives I-1 and I-2 perform better with higher peak, median, and mean wetted floodplain area than the No Action Alternative with 500 and 1,000 cfs diversions, respectively.

Support for native vegetation was also evaluated by considering the average annual acre-days of inundation for Hink and Ohmart vegetation classification Types 1, 2, 3, and 5; and for Fish and Wildlife Service (FWS) Resource Category Types 2 and 3 (See Chapter 3, Section 3.3.1.2 for definition of types.) The degree to which alternatives may negatively impact riparian corridors by providing unwanted support to invasive species was also evaluated. **Figure 4-19** summarizes alternative performance relative to total days of inundation in desirable native vegetation types. The acre-days of inundation ranged from 92 (No Action) to 2142 (I-1) in the Rio Chama; from 8,730 (I-3) to 11,125 (E-3) in the Central Section, and from 72,340 (B-3) to 188,060 (No Action-0 cfs to LFCC). Overall, the rank order of alternatives for native vegetation community support is as follows: I-1, I-2, D-3, E-3, No Action, I-3, and B-3.

Sources of Uncertainty and Data Gaps

The primary tools used in the riparian analysis included vegetation inventory and classification maps, results from the URGWOM planning model, FLO-2D model, and aquatic habitat models. The quality and limitations of each data set depend on modeled data and uncertainties in input data, including gage error and hydrologic inputs. Full alternative impact modeling was performed only for No Action at zero diversions to the LFCC in order to provide a baseline comparison. This is especially of interest in the San Acacia Section, because diversion to the LFCC is one of the primary causes of impact in this section. Where analyses offered a means to discriminate between No Action at a specified diversion to the LFCC and an alternative with the same diversion to the LFCC, more direct comparisons were provided.

The FLO-2D model is most precise and accurate for the Rio Chama and Central Sections, but is less reliable in the San Acacia Section due to streambed instability. The HEC-RAS model was used to predict inundation south of Bosque del Apache NWR to the power lines at the full pool of Elephant Butte Reservoir. Using GIS and database analysis, these predictions were added to FLO-2D predictions above San Marcial to predict inundation for the San Acacia Section.

Summary/Comparison by Alternative: Riparian Habitat Analysis

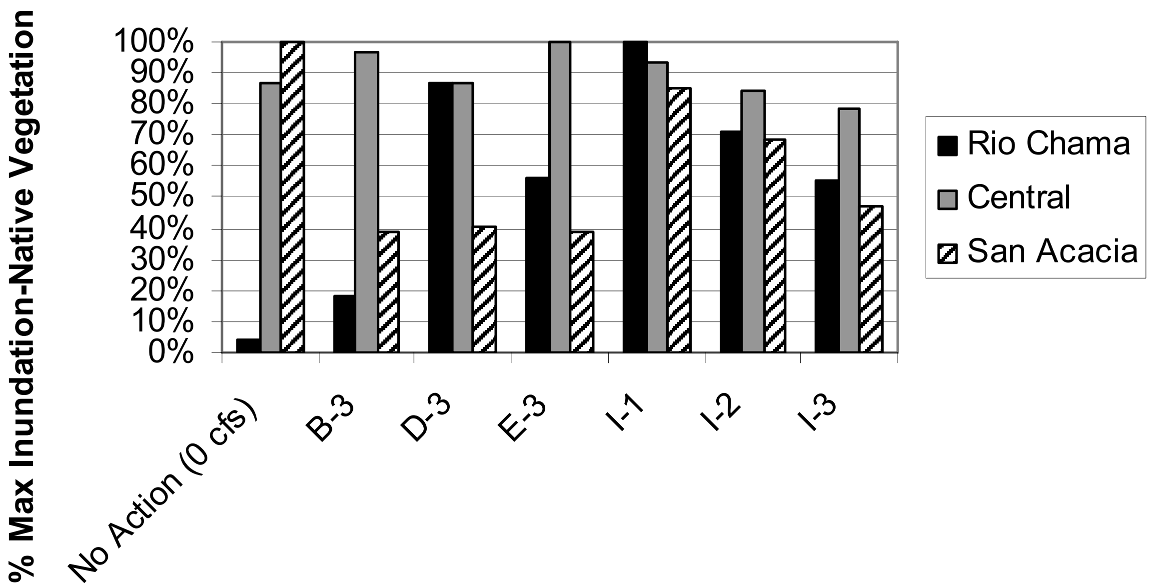


Figure 4-19. Percent of Maximum Possible Inundation of Native Vegetation Communities by River Section and Alternative

Figure 4-19 provides a comparison of two riparian performance measures in the San Acacia Section that would be affected by diversions to the LFCC. Adverse biological effects of any alternative would be proportional to the amount of diversion to the LFCC actually implemented in the proposed project. The effect of a decrease in overbank flooding from diversion of up to 500 cfs would probably not have a significant effect on riparian resources, but might require monitoring of endangered species habitats to assure that this level of diversion does not have an adverse effect. With diversions capped at 1,000 cfs, both the frequency and amount of overbank flooding would be adversely affected. With diversions of up to 2,000 cfs, the frequency of flooding would decrease by 5 percent, resulting in significant adverse impacts to resources.

The effect of diversions of 1,000 and 2,000 cfs to the LFCC would likely produce significant adverse impacts to riparian resources in the San Acacia Section, including riparian habitats and fauna, natural management areas, wetlands, and threatened and endangered species such as nesting southwestern willow flycatcher (SWFL) populations.

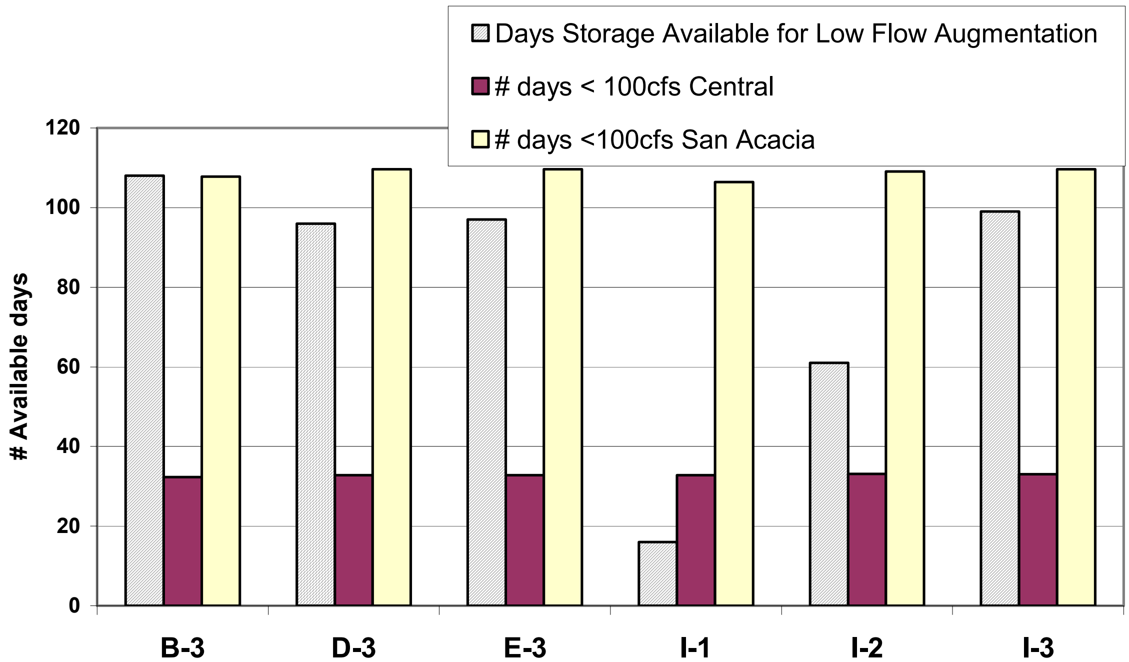
The degree of support for various types of vegetation provided by the alternatives, in comparison to No Action, is summarized in **Table 4-8**. It is important to note that for the San Acacia Section, all comparisons were initially performed against No Action with zero diversion to the LFCC. Consequently, the magnitude of habitat loss is roughly correlated to the level of diversion to the LFCC. Alternatives with 2,000 cfs LFCC diversions (B-3, D-3, E-3, and I-3) have the largest projected habitat losses, with lesser impacts associated with 500 and 1,000 cfs diversions (I-1 and I-2, respectively). Subsequent evaluations for habitat changes comparing equivalent diversions to the LFCC yield overall increases in riparian habitat for Alternatives E-3, I-1, I-2, and I-3, and no significant changes for Alternatives B-3 and D-3.

Table 4-8. Change in Riparian Habitat Support Relative to No Action

	B-3	D-3	E-3	I-1	I-2	I-3
Rio Chama Section						
Supports Hink & Ohmart Vegetation Types I & II	**156%**	**1,180%**	**780%**	**1,460%**	**1,020%**	**780%**
Supports Hink & Ohmart Vegetation Types III & V	**366%**	**2,011%**	**1,235%**	**2,122%**	**1,604%**	**1,228%**
Supports FWS Type 2	**339%**	**1,861%**	**1,206%**	**2,072%**	**1,564%**	**1,197%**
Supports FWS Type 3	**267%**	**2,117%**	**1,267%**	**2,167%**	**1,650%**	**1,258%**
Central Section						
Supports Hink & Ohmart Vegetation Types I & II	9%	-1%	**12%**	8%	-3%	**-10%**
Supports Hink & Ohmart Vegetation Types III & V	**13%**	1%	**17%**	7%	-4%	-9%
Supports FWS Type 2	**13%**	0%	**17%**	8%	-3%	**-10%**
Supports FWS Type 3	8%	0%	**12%**	7%	-2%	-9%
San Acacia Section						
Supports Hink & Ohmart Vegetation Types I & II	**-80%**	**-79%**	**-79%**	**-18%**	**-28%**	**-62%**
Supports Hink & Ohmart Vegetation Types III & V	**-64%**	**-61%**	**-62%**	**-15%**	**-31%**	**-53%**
Supports FWS Type 2	**-56%**	**-55%**	**-56%**	**-14%**	**-33%**	**-52%**
Supports FWS Type 3	**-74%**	**-71%**	**-75%**	**-16%**	**-25%**	**-55%**
Change in Riparian Habitat Support Relative to Equivalent No Action Diversion to LFCC	**3%**	**-3%**	**15%**	**16%**	**24%**	**36%**

Notes: Negative values represent loss of habitat.
■ (grey) = Beneficial impacts
■ (black) = Adverse impacts

Figure 4-20 represents the potential number of days available for low flow augmentation in the Central and San Acacia Sections. It was assumed that 50 percent of the conservation storage in Abiquiu Reservoir was available for low flow augmentation. The number of low flow augmentation days only surpasses the number of predicted days less than 100 cfs in the Central and San Acacia Sections under Alternative B-3. This would help mitigate the effects of 0 to 100 cfs days on riverine habitat and fish communities. All other alternatives would not have enough augmentation days to cover the predicted number of low flow days for both sections. Alternative I-1 would not be able to mitigate for 16 and 100 days for the Central and San Acacia Sections, respectively. Alternatives D-3, E-3 and I-3 could mitigate low flow days for the Central Section but would require approximately 10 additional days for the San Acacia Section. Alternative I-2 could also mitigate low flow days for the Central Section but would require 48 additional days for the San Acacia Section.



Note: Averaged over the 40-year planning period. Augmentation flow is defined as an additional 150 cfs release from Abiquiu to the particular low flow event.

Figure 4-20. Average Annual Days Available for Low Flow Augmentation in Central and San Acacia Sections by Alternative

Evaluation of the impacts of varying levels of LFCC diversion on groundwater elevation and acres of wetlands used URGWOM and MODBRANCH in conjunction with GIS. **Figure 4-21** shows monthly changes in groundwater elevation for LFCC diversions at 0, 1,000, and 2,000 cfs. Diversion to the LFCC supports wetland habitats immediately adjacent to the LFCC, with lesser support east of the river, especially if all river flow is diverted to the LFCC. **Figure 4-22** shows the spatial shift in wetlands supported by LFCC diversions at 0, 1,000 and 2,000 cfs on wetland areas from Bosque del Apache NWR south to Fort Craig above Elephant Butte Reservoir. Diversions at 1,000 cfs and a 250 cfs bypass increased wetland habitat supported by almost 2.0 acres above the 14.5 acres supported by No Action with 0 cfs diverted to the LFCC. Diversions at 2,000 cfs with no bypass to the river decreased wetland habitat supported by about 1.4 acres as compared to No Action.

Compared to the No Action Alternative, modeled with zero diversions to the LFCC, riparian benefits were generally not evident under the action alternatives. Alternative I-1 would result in the fewest adverse impacts across the three sections of the river summarized in **Table 4-9**.

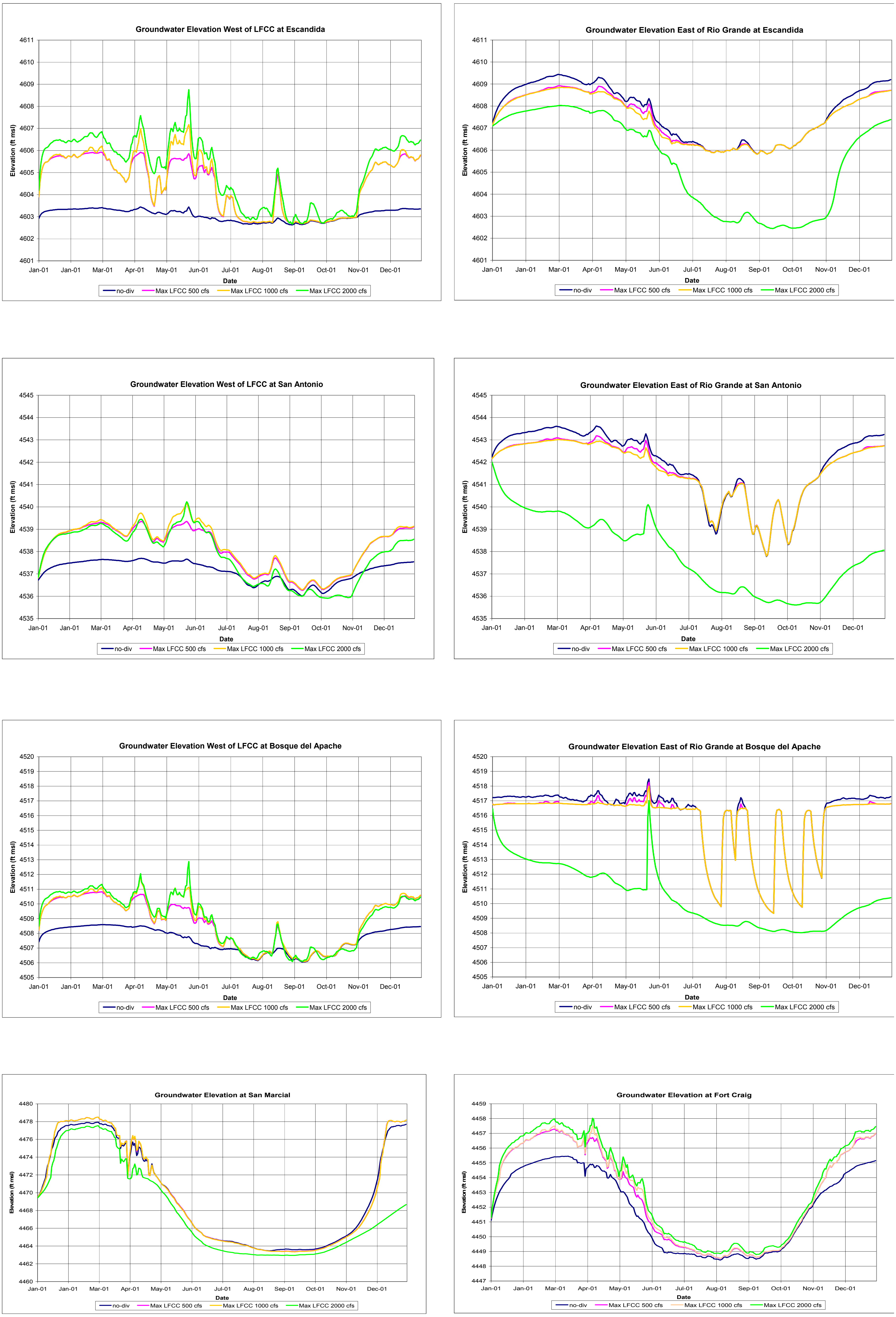


Figure 4-21. San Acacia Section: Changes in Water Table Elevation with Increasing LFCC Diversion

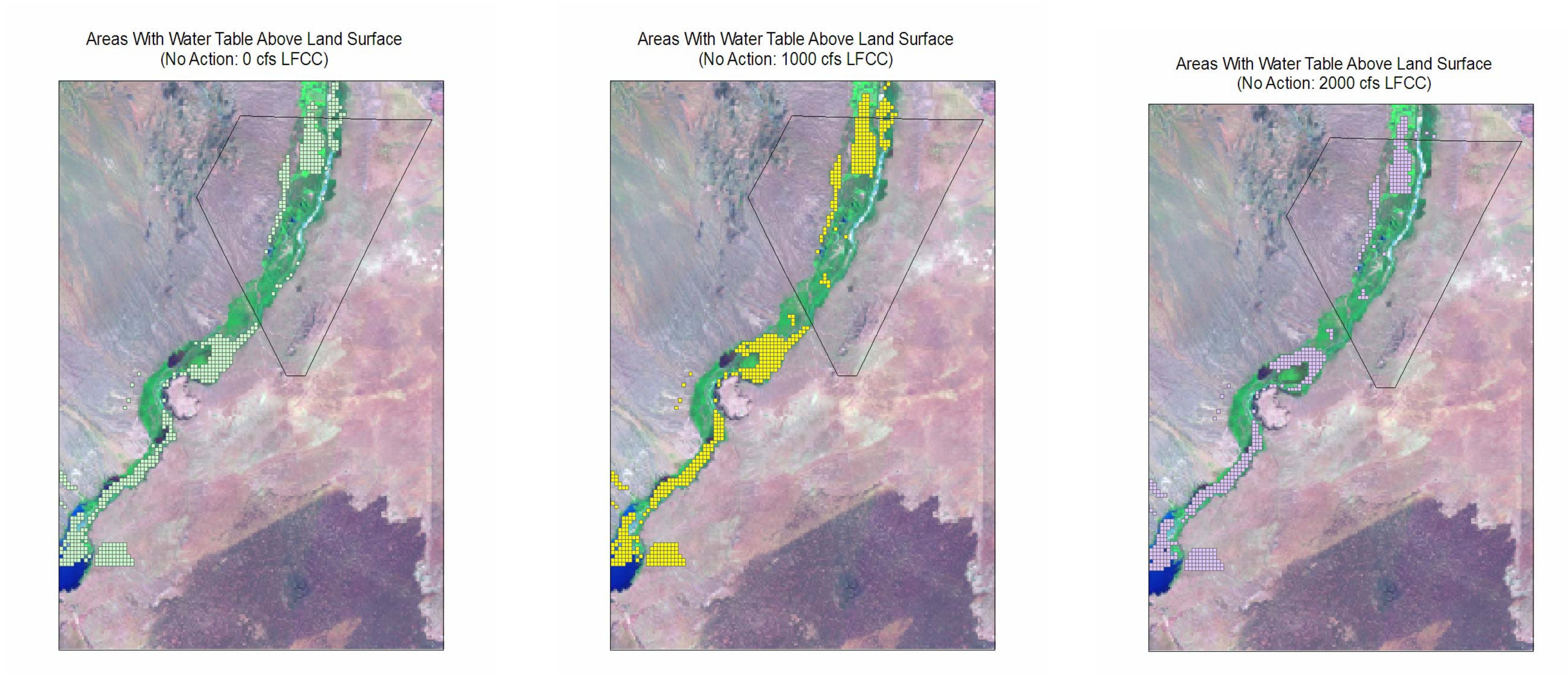


Figure 4-22. San Acacia Section: Locations Where Water Table Elevation Exceeds Land Surface Elevation

4-9. Impacts to Riparian Resources by River Section and Alternative

Alternative	Rio Chama Section	Central Section	San Acacia Section
No Action: LFCC = 0 cfs	No effect	Continued adverse impacts	Continued benefits
No Action: LFCC = 500 cfs	No effect	Continued adverse impacts	Slight adverse impacts
No Action: LFCC = 1,000 cfs	No effect	Continued adverse impacts	Slight beneficial impacts
No Action: LFCC = 2,000 cfs	No effect	Continued adverse impacts	Significant adverse impacts
Alternative B-3	Significant adverse impacts	Benefits	Slight beneficial impacts compared to No Action at 2,000 cfs
Alternative D-3	Benefits	No effect	Significant adverse impacts compared to No Action at 2,000 cfs
Alternative E-3	Potential adverse impacts	Benefits	Slight beneficial impacts compared to No Action at 2,000 cfs
Alternative I-1	No effect	No effect	Potential beneficial impacts compared to No Action at 500 cfs
Alternative I-2	No effect	No effect	Potential beneficial impacts compared to No Action at 1,000 cfs
Alternative I-3	Benefits	No effect	Potential beneficial impacts compared to No Action at 2,000 cfs

Note: *No effect* means there is no significant impact to riparian resources.

The distribution of ecosystem benefits by river section is shown on **Figure 4-23**. Alternatives I-1 and I-2 perform better at equalizing riparian resource benefits across the Rio Chama, Central, and San Acacia sections. The remaining alternatives perform better in one or two sections, at the expense of the third. Riparian habitat in the San Acacia Section is typically most affected by the level of LFCC diversion.

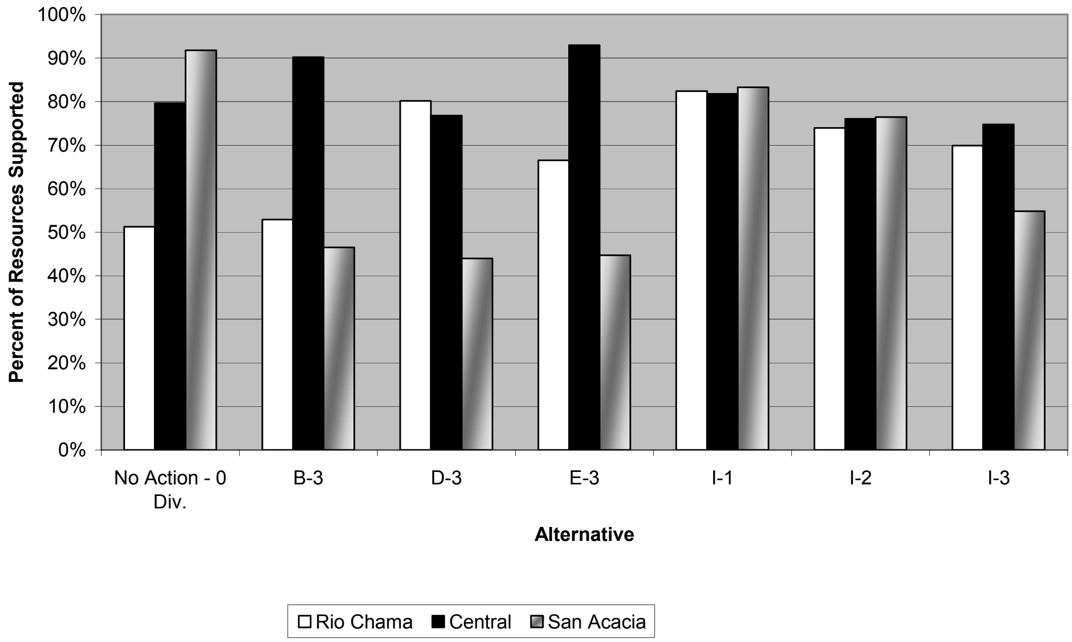


Figure 4-23. Riparian Resources Supported by River Section and Alternative

Support for riparian habitats, including threatened and endangered species, is summarized in **Figure 4-24**. Alternative I-1 offers significant improvement over No Action with zero diversions to the LFCC. Alternative I-2 offers slightly improved conditions for riparian resources. No Action with zero diversions to the LFCC is only slightly better than the alternatives allowing a full 2,000 cfs diversion – Alternatives E-3, I-3, D-3, and B-3. The overall difference in weighted resource performance measures between the No Action and the remaining alternatives is less than 5 percent.

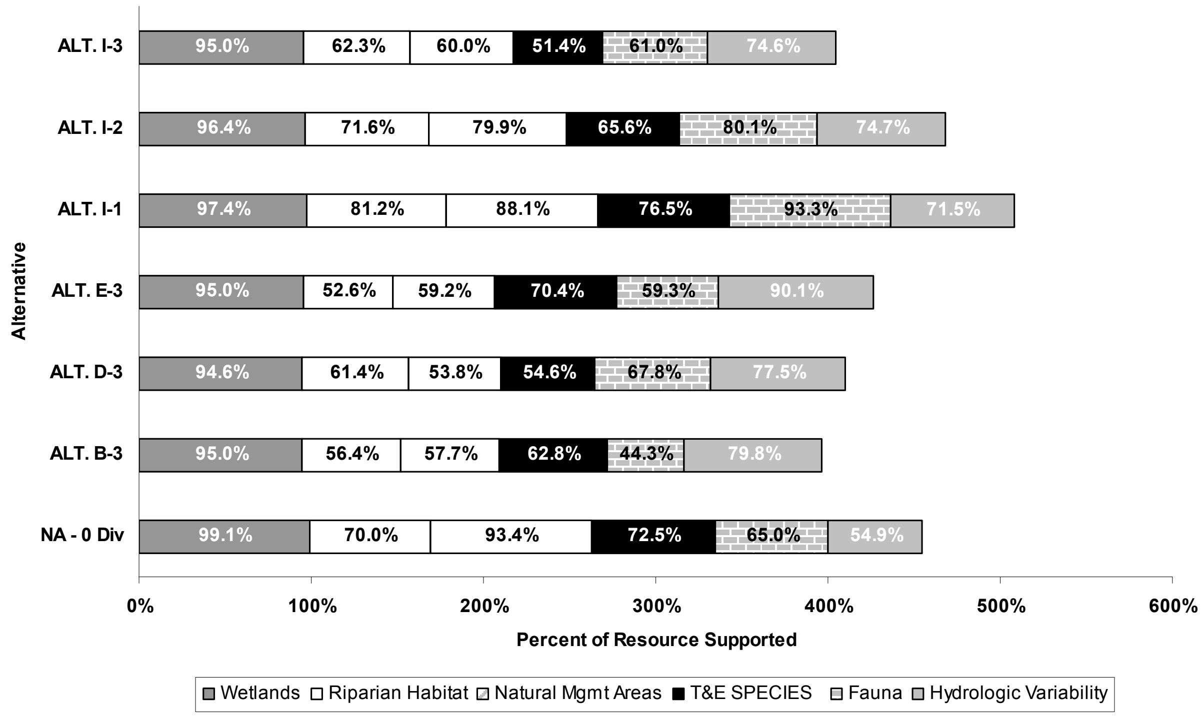


Figure 4-24. Riparian Resources Support by Alternative

Mitigation Measures

Mitigation needs for riparian resources include periodic overbank flooding to support the regeneration of native riparian vegetation, which provides high habitat diversity for wildlife. Hink and Ohmart Type 3 vegetation supports the greatest biodiversity, followed by Types 1 and 5. During extended dry periods, the use of conservation water to promote overbank flooding needed to maintain and sustain these habitats is advocated. **Figure 4-25** shows the correlation between peak flow and riparian acres flooded, by reach. Reaches 10, 12, and 13 are in the Central h 14 is the San Acacia Section.

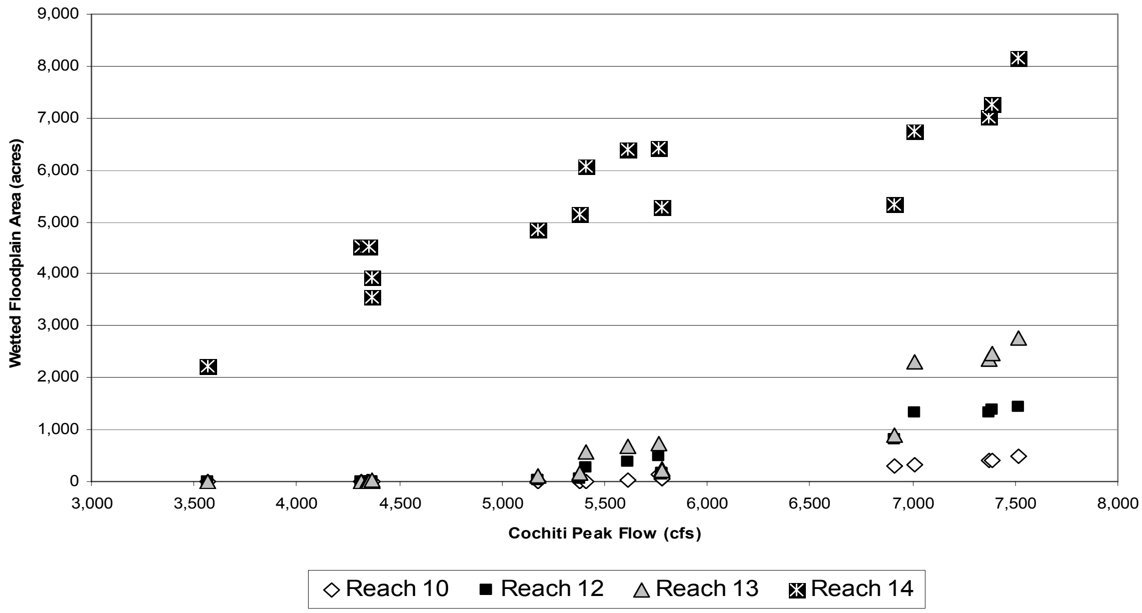


Figure 4-25. Wetted Floodplain Area versus Cochiti High Flow

The following is a list of mitigation measures to be considered for the benefit of both riparian and aquatic environments beyond the March 2003 Biological Opinion.

- Operate the LFCC in order to preserve ecosystem function and benefits from higher flows along the main river channel.
- Release conservation storage to maintain desired target flows, to reduce intermittency, and to minimize low flow days.
- Release conservation storage to increase spring peak flows in order to promote RGSM spawning and increase overbank flooding.
- Secure carryover storage agreements for conservation water that could be held over to support future ecosystem needs.
- Moderate abrupt changes to flow that could potentially strand fish and decrease support for cottonwood regeneration by ramping down reservoir release rates to slow the rate of decline.
- Monitor populations and impact indicators in order to implement adaptive management.

4.4.2.3 Threatened and Endangered Species

Issues

Of the five federally-listed threatened and endangered species identified in Chapter 3, the RGSM, the SWFL, and bald eagle were considered in the impact analysis. The interior least tern and brown pelican are only occasional migrants and were not considered further. Impacts to the New Mexico meadow jumping mouse, a state-listed threatened species, were also evaluated.

The RGSM, once abundant in the Rio Grande, is now extirpated, except in the Central and San Acacia Sections. The impact analysis also considered whether suitable habitat may be present in the Rio Chama Section. Critical habitat elements required to sustain the RGSM include favorable stream morphology and sufficient flowing water that provides food and cover for all life stages. Water quantity provides continuous flows that enable fish movement, limits predation by birds and aquatic predators, and provides sufficient habitat area to limit the spread of disease-causing pathogens. Water quantity also relates to water quality in that it prevents water stagnation and the undesirable increases in temperature and decreases in dissolved oxygen.

The SWFL is a riparian obligate that nests in thickets associated with streams and wetlands. Willow, buttonbush, box elder, Russian olive, and saltcedar are among the desirable species. Breeding territories are typically located in dense vegetation within 164 feet (50 meters) of open water. Territories tend to occur in clusters, within approximately 10 miles of each other. SWFL return to established nesting sites annually. The SWFL Recovery Plan (FWS 2002a) outlines the desired recovery goals, and Table 3-7 outlines the recovery goal territories by river section. Alternatives will be evaluated based on overall support to suitable SWFL habitat and by progress towards recovery goals.

The bald eagle is a threatened species that winters along the Rio Grande from November through March. It prefers to roost in large trees near water, typically where large cottonwoods occur at the river's edge or in large snags near reservoirs. Prey includes fish, waterfowl, and small mammals. The impact analysis will consider effects on availability of roost sites and impacts to prey bases.

The New Mexico meadow jumping mouse is a New Mexico Department of Game and Fish (NMDGF) threatened species. The meadow mouse requires dense vegetation found in marshes, moist meadows, and riparian habitats. It is also occasionally found in constructed habitats including irrigation drains and canals. The meadow jumping mouse has been reported in the Northern, Rio Chama, Central, and San Acacia Sections, with key wetland habitats identified in Espanola, Rio Cebolla, Isleta Marsh, and Bosque del Apache NWR. Wetland and wet meadow support are the key factors used to assess impacts to this state-listed species.

General Conclusions

Impacts to the various threatened and endangered species vary, and are discussed by each species as follows. In general, Alternatives I-1, I-2, E-3, and D-3 provided the best support when comparing across all species evaluated.

Evaluation of impact to the RGSM included an analysis of suitable habitat at various life stages using the aquatic habitat model. The RGSM is best supported across the Rio Chama, Central, and San Acacia sections with potentially suitable habitat as follows: I-1, I-2, E-3, D-3, I-3, B-3, and No Action. If habitat improvements in the Rio Chama are excluded because the RGSM is considered extirpated in this section of the river, the top two alternatives remain I-1 and I-2, with the rank order for the remaining alternatives changing as follows: No Action, D-3, E-3, I-3, and B-3.

Opportunities exist among the action alternatives to potentially improve the range of SWFL by increasing the availability of suitable habitat in the Rio Chama and Central Sections. Support for suitable SWFL habitat in the San Acacia Section is related to the magnitude of diversion to the LFCC. All action alternatives support territory goals identified in the SWFL Recovery Plan (FWS 2002a). However, increasing diversion to the LFCC reduces support for riparian habitat adjacent to the river in the San Acacia Section, with a 57 percent reduction in flooded acres observed when comparing 0 cfs to a 2,000 cfs diversion to the LFCC. However, all action alternatives, with the exception of D-3, offer potential improvements in wetted floodplain acres as compared to the No Action Alternative at similar levels of diversion. Alternative rank in order of preference for supporting SWFL habitat in the Rio Chama, Central, and San Acacia Sections in accordance with Recovery Plan goals is as follows: E-3, I-1, I-2, B-3, D-3, I-3, and No Action.

The bald eagle is not expected to be significantly affected by any of the alternatives. Changes in elevation at Abiquiu Reservoir increase due to the addition of native conservation storage and this offers potential enhancements in supporting the prey base. Changes in average monthly water elevation at Heron and Cochiti Reservoirs were not significantly different between alternatives. Effects of elevation changes in Elephant Butte and Caballo Reservoirs were not considered because this EIS considered changes only to flood control operations and not water supply.

Alternatives I-2, I-1, and No Action with LFCC diversions up to 1,000 cfs best support the wet meadow, marsh, and wetland areas frequented by the New Mexico meadow jumping mouse. Of the remaining alternatives with 2,000 cfs diversions to the LFCC, alternatives with higher channel capacities below Cochiti (E-3 and D-3) offer better support than I-3 or B-3.

Impact Indicators

Impact indicators were selected based on considerations for specific species habitat and life-stage needs.

Rio Grande Silvery Minnow—Changes in square feet of RGSM habitat were ranked by alternative considering the duration of overbank flooding, the average number of days of zero cfs flow, the average number of low flow days (less than 100 cfs), the average peak flow magnitude, and the average peak flow duration. The threshold velocity for hatching and retention of RGSM eggs in the Central and San Acacia Sections was calculated to be 1.85 feet per second. Velocities in excess of this threshold result in increased egg and larval mortality as they drift into Elephant Butte Reservoir. It is assumed that there is no recruitment of RGSM eggs or larvae in the reservoir. Reservoir habitats are not suitable for RGSM and were not evaluated further.

Southwestern Willow Flycatcher—Suitable SWFL habitat within reasonable proximity to open water was evaluated using indicators determined from the FLO-2D model including: the 40-year frequency of inundation, mean and maximum durations of dry years, mean annual acre-days of inundation, and maximum annual acre-days of inundation. More value was assigned to inundation of suitable habitat within 10 miles of currently occupied habitat due to the increased probability of SWFL expansion into areas adjacent to existing territories.

Bald Eagle—Nesting bald eagles are documented only in a few locations in New Mexico, none of which are in the planning area. Bald eagles are winter residents and most closely associated with reservoirs along the Rio Chama and Rio Grande. Impacts to bald eagles were qualitatively evaluated considering potential water operations impacts on perch/roost structures and foraging habitat.

New Mexico Meadow Jumping Mouse—Impacts to the meadow jumping mouse were evaluated considering the average annual acre-days of flooding by vegetation type to assess the hydrological support for preferred habitat. GIS overlays of vegetation mapping and FLO-2D data were used to quantitatively assess differences between alternatives. It was assumed that the baseline condition would be to maintain existing meadow jumping mouse habitat.

Methods of Analysis

Three federally-listed and one state-listed species were considered in the impact analysis, based on their known occurrence in areas most likely to be affected by changes in water operations. Quantitative analysis was based on data predicting flow-based changes in suitable habitat. Qualitative analysis was used where specific data were not available.

The RGSM impact analysis considered the URGWOM flow data, FLO-2D predictions of inundation, and the aquatic habitat modeling results for each alternative, in order to provide quantitative predictions of changes in suitable habitat.

The SWFL impact analysis used GIS overlays of vegetation mapping with inundation predicted by FLO-2D and SWFL occupied habitat patches (1999-2004). The FLO-2D model evaluated SWFL habitat quality using surrogate measures such as: 40-year frequency of inundation, mean and maximum durations of dry years, mean annual acre-days of inundation, and maximum annual acre-days of inundation. Based on prior SWFL habitat use along the middle Rio Grande and habitat requirements provided in the Recovery Plan (USFWS 2002), the most suitable SWFL breeding habitat was identified using Hink and Ohmart vegetation types. Occupied SWFL breeding sites within suitable vegetation types that are within 164 feet (50 meters) of surface water were overlain with FLO-2D inundation results to evaluate suitable habitat within 10-miles of occupied sites as well as at distances greater than 10 miles from occupied sites.

Qualitative analysis of changes in reservoir elevation in supporting perch/roost sites and foraging habitat for the bald eagle was used to evaluate impacts to this species.

Wet meadow habitat support was used to assess impacts to the New Mexico meadow jumping mouse. This analysis used GIS overlays of the inundated vegetation types to predict changes in wet meadow habitat support.

Thresholds for Significance

The significance of adverse impacts could only be determined through assessment of species status and the intensity of measurable impacts. For example, endangered species within designated critical habitat are considered to have the most sensitive context wherein even minor adverse impacts would be considered significant.

Discussion of Results of Analysis

Rio Grande Silvery Minnow—The status of the RGSM is expected to remain unchanged under the No Action Alternative, with no diversions to the LFCC. This alternative would provide fewer overbank flooding durations in the Rio Chama Section—which is beyond the current range of the species. This alternative would support habitat in the Central Section, but would provide only about half (52 percent) of the potential acres of overbank flooding supported by other alternatives. The No Action Alternative, assuming zero diversions to the LFCC, would benefit species habitat in the San Acacia Section; however, if full 2,000 cfs diversions to the LFCC were implemented, adverse impacts could be anticipated. Baseline habitat conditions under the No Action Alternative are shown in **Table 4-10**.

Table 4-10. Minnow Habitat Area by Life Stage and Section

Section	No Action (acres)	
	Juvenile	Adult
Rio Chama	<1	<1
Central	22	27
San Acacia	9	11

The lack of upstream storage limits the ability to find supplemental water, to augment high flows, and to avoid periods of intermittent flow. Within the past few years, upstream storage was used to supplement flows under emergency conditions in response to drought, requiring deviations in operations to be approved on a case-by-case basis with species-specific NEPA compliance.

The No Action Alternative would offer the least flexibility in storing upstream native Rio Grande water to support ecological needs. As modeled, it would offer a view of the maximum riverine hydrology available without supplemental water inputs. However, improvements for this listed species would likely require additional water storage that would be better supported by other alternatives. The greatest potential adverse effect would be entrainment of RGSM during diversions to the LFCC.

Limited data are available regarding the entrainment of RGSM eggs in the LFCC. Currently there are ongoing projects funded by Reclamation examining entrainment in the LFCC during peak spawning season. Previous studies by Smith (1999) found evidence of RGSM eggs in the LFCC, but were unable to identify a significant difference between the numbers of eggs entering the LFCC and the number of eggs exiting through the LFCC temporary outfall. Recent reports suggest that many viable RGSM eggs and larvae which survive do not travel far downstream (Reclamation 2004).

Although RGSM has been extirpated from the Rio Chama Section, both juvenile and adult spring habitat area would improve under all action alternatives, as shown in **Table 4-11**. However, on an annual basis, RGSM general habitat area would decrease for all action alternatives. In the Central Section, there would be no significant difference for all habitat areas and life stages. In the San Acacia Section, there would be decreases in RGSM habitat ranging from 4 to 20 percent, primarily dependent on the degree of diversion to the LFCC. Spring habitat losses could potentially be mitigated using conservation storage.

Table 4-11. Riverine Habitat for Adult and Juvenile RGSM by Alternative

Alternative	Percent Change Relative to the No Action Alternative at 0 cfs Diversion to the LFCC								
	Rio Chama Section			Central Section			San Acacia Section		
	RGSM Juvenile Habitat Spring	RGSM Adult Habitat Spring	RGSM General Habitat Annual	RGSM Juvenile Habitat Spring	RGSM Adult Habitat Spring	RGSM General Habitat Annual	RGSM Juvenile Habitat Spring	RGSM Adult Habitat Spring	RGSM General Habitat Annual
B-3	2	4	-7	1	-2	-2	-15	-16	-20
D-3	5	6	-3	1	-1	-1	-16	-16	-20
E-3	5	6	-4	1	-1	-2	-15	-16	-20
I-1	<1	<1	-3	<-1	<-1	<-1	-4	-4	-9
I-2	2	2	-4	<1	-1	-2	-9	-9	-16
I-3	5	6	-4	<1	-1	-2	-16	-16	-20

Notes: "General" includes juvenile and adult populations. Negative values represent loss of habitat.
☐ = Beneficial impacts
■ = Adverse impacts

More detailed examination of the impacts of LFCC diversion on RGSM habitat was performed to better differentiate between effects of LFCC diversion and effects of change in other water operations. **Table 4-12** shows a detail of sensitivity analyses performed for varying levels of LFCC on RGSM habitat by life stage for the San Acacia Section. Total RGSM habitat area for the alternatives is provided for comparison. RGSM habitat under varying diversions to the LFCC ranges from 9.5 to 11.7 acres. Alternatives I-1 and I-2 provide RGSM habitat within 0.1 acres of the corresponding LFCC diversion under No Action. Alternatives B-3, D-3, E-3, and I-3 all result in 0.7 acre reductions in RGSM habitat when compared to No Action at the comparable 2,000 cfs LFCC diversions. Thus, reductions in RGSM habitat are approximately 7 percent in the San Acacia Section, with the remaining 7 to 15 percent reductions shown on Table 4-12 above attributed to the 2,000 cfs LFCC diversion.

Table 4-12. RGSM Riverine Habitat by Life Stage – San Acacia Section Detail

RGSM Habitat by Life Stage	Aquatic Habitat Model Site	Habitat Area (ft^2)										
		NA-0 cfs	NA-500 cfs	I-1	NA-1,000 cfs	I-2	NA-1,500 cfs	NA-2,000 cfs	B-3	D-3	E-3	I-3
Juvenile	Bosque del apache NWR	364,851	306,171	307,365	271,748	275,019	261,397	284,466	250,279	251,144	251,579	250,954
	San Marcial	90,939	102,381	99,399	103,528	102,122	105,074	102,238	109,879	108,372	108,974	108,614
	TOTAL	455,790	408,552	406,765	375,276	377,141	366,471	386,704	360,157	359,516	360,553	359,568
	Acres	10.5	9.4	9.3	8.6	8.7	8.4	8.9	8.3	8.3	8.3	8.3
Adult	Bosque del Apache NWR	440,529	374,406	375,386	331,638	335,219	318,132	345,658	304,595	305,495	306,052	305,267
	San Marcial	126,617	138,040	135,048	138,440	137,933	140,542	137,586	148,542	146,258	147,154	146,627
	TOTAL	567,146	512,446	510,434	470,078	473,152	458,674	483,244	453,137	451,752	453,206	451,895
	Acres	13.0	11.8	11.7	10.8	10.9	10.5	11.1	10.4	10.4	10.4	10.4
Total Acres RGSM Habitat	Bosque del apache NWR	18.5	15.6	15.7	13.9	14.0	13.3	14.5	12.7	12.8	12.8	12.8
	San Marcial	5.0	5.5	5.4	5.6	5.5	5.6	5.5	5.9	5.8	5.9	5.9
	Total Acres RGSM Habitat	**23.5**	**21.1**	**21.1**	**19.4**	**19.5**	**18.9**	**20.0**	**18.6**	**18.6**	**18.7**	**18.7**
Percent RGSM Habitat at Model Sites	Bosque del apache NWR (40.2 acres)	46%	39%	39%	34%	35%	33%	36%	32%	32%	32%	32%
	San Marcial (15.5 acres)	32%	36%	35%	36%	36%	36%	36%	38%	38%	38%	38%

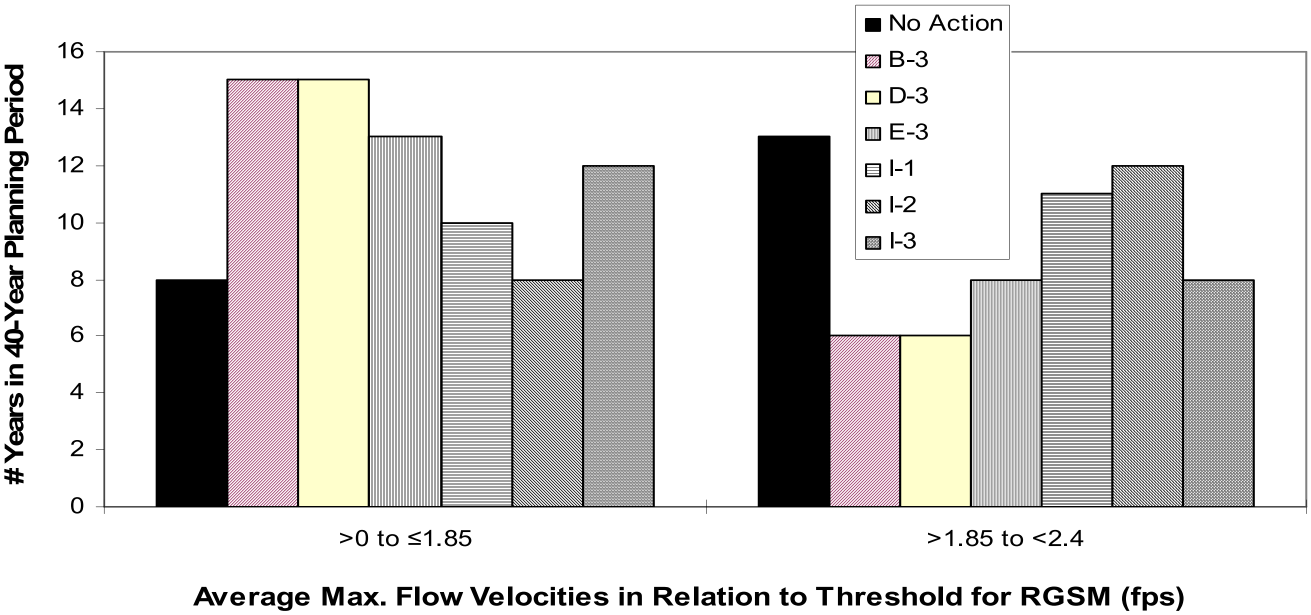


Figure 4-26. Frequency of Threshold Velocity Exceedance During Years of Overbank Flooding in the Rio Grande from Angostura Diversion Dam to Elephant Butte Reservoir

Southwestern Willow Flycatcher—The effects of the No Action Alternative on the endangered SWFL are not uniform in the planning area, as shown in **Tables 4-13** and **4-14**. In the Rio Chama and Central Sections, the No Action Alternative may not provide sufficient frequency or extent of overbank inundation to meet recovery goals identified in the SWFL Recovery Plan (FWS 2002). However, continued benefits to SWFL habitat would be anticipated in the San Acacia Section under the No Action if no diversions to the LFCC were implemented during the 40-year period.

No Action with 0 cfs diversions to the LFCC would provide the best support to occupied SWFL sites and suitable habitat in the San Acacia Section, which has the greatest number of occupied sites and largest acreage of suitable habitat within 10 miles of occupied sites. By contrast, the No Action Alternative would provide less support to the Rio Chama and Central Sections. Suitable habitat within 10 miles of occupied sites in the Rio Chama Section would receive inundation during 67 percent of the years, with an annual average of 0.7 acre-days of inundation. Suitable habitat less than 10 miles from occupied territories in the Central Section would receive an annual average of 530 acre-days of flooding during 16 percent of the years. Overall, this alternative would provide the least support to suitable habitat of any of the alternatives in the Rio Chama Section.

The overall average performance of the No Action Alternative with zero diversions to the LFCC would be beneficial to the species, given the large areas of habitat supported in the San Acacia Section. It would provide the flows necessary to maintain and expand the population in the Middle Rio Grande SWFL Recovery Unit. However, this alternative would not assist in reaching SWFL Recovery Plan goals for expanding the population by increasing the extent and duration of overbank flooding and establishing and supporting suitable habitat in the Upper Rio Grande Unit.

Impacts of different levels of diversion into the LFCC would have an increasing adverse effect to flycatcher territories along the Rio Grande, but there would be some beneficial effects to territories located at the existing LFCC outfall. The total area of floodplain inundation averaged over the 40-year planning period would decrease by 16 percent with 500 cfs diversions, 34 percent with 1,000 cfs diversions, and 67 percent with 2,000 cfs diversions, as shown in Figure 4-19.

Bald Eagle—Impacts to bald eagle habitat include decreasing available roost sites (tall snags) near suitable open water foraging areas, reducing the aquatic habitat supporting the eagle's prey base, or increasing the distance from suitable roosting habitat to open water feeding areas. All action alternatives increase average monthly reservoir elevations when compared to No Action. None of the action alternatives are expected to result in adverse effects to bald eagles at the key reservoirs, as increased water storage is anticipated under all scenarios when compared to No Action. While it would be difficult to detect and measure impacts to bald eagle habitat parameters in the planning area for any of the alternatives, any potential impacts to roost sites or prey base in the planning area as a result of this alternative are expected to be insignificant.

Table 4-13. Impacts of SWFL Habitat Inundation

Measure	SWFL Habitat Class	Alternative	Section					
			Rio Chama	Central	San Acacia			
					LFCC Diversion			
					0 cfs	500 cfs	1,000 cfs	2,000 cfs
Average Inundated Acres		No Action			3,788	3,236	2,680	1,615
						85%	71%	43%
Mean Annual Days Inundation - Occupied Sites	Occupied Sites	No Action	No Territories	10	462			
		B-3	No Territories	37				100
		D-3	No Territories	10				116
		E-3	No Territories	39				102
		I-1	No Territories	11		391		
		I-2	No Territories	10			383	
		I-3	No Territories	9				200
Mean Annual Acre-Days Inundation - Suitable Habitat	Suitable Habitat <10 miles from Core Areas	No Action	11	888	20,374			
		B-3	72	1,010				8,789
		D-3	200	903				9,177
		E-3	141	1,063				8,842
		I-1	238	950		17,615		
		I-2	179	872			13,552	
		I-3	140	817				9,621
Mean Annual Acre-Days Inundation - Suitable Habitat	Suitable Habitat >10 miles from Core Areas	No Action	21	584	3,476			
		B-3	21	618				584
		D-3	219	582				648
		E-3	109	645				572
		I-1	174	625		2,861		
		I-2	138	564			2,654	
		I-3	108	527				1,392

Measure	SWFL Habitat Class	Alternative	Section					
					San Acacia			
					LFCC Diversion			
			Rio Chama	Central	0 cfs	500 cfs	1,000 cfs	2,000 cfs
Mean Annual Acres Inundated	Suitable Habitat <10 miles from Core Areas	No Action	14	33	345			
		B-3	6	57				224
		D-3	12	36				221
		E-3	9	63				224
		I-1	14	37		322		
		I-2	11	34			308	
		I-3	9	30				237
Mean Annual Acres Inundated	Suitable Habitat >10 miles from Core Areas	No Action	5	22	106			
		B-3	1	35				29
		D-3	10	23				25
		E-3	4	40				27
		I-1	5	25		99		
		I-2	5	23			95	
		I-3	4	20				50

Table 4-14. Frequency of Inundation and Duration of Dry Years—SWFL Habitat

Measure	SWFL Habitat Class	Alternative	Section					
			Rio Chama	Central	San Acacia			
					LFCC Diversion			
					0 cfs	500 cfs	1,000 cfs	2,000 cfs
40-year Frequency of Inundation (percent)	Occupied Sites	NA	No Territories	17	53			
		B-3	No Territories	25				40
		D-3	No Territories	20				43
		E-3	No Territories	23				38
		I-1	No Territories	20		53		
		I-2	No Territories	20			50	
		I-3	No Territories	18				48
40-year Frequency of Inundation (percent) °	Suitable Habitat <10 miles from Core Areas	NA	90	50	100			
		B-3		48				90
		D-3		48				90
		E-3						90
		I-1	90	53		95		
		I-2	85	50			90	
		I-3		48				90
40-year Frequency of Inundation (percent)	Suitable Habitat >10 miles from Core Areas	NA	90	50	53			
		B-3	85	48				30
		D-3	85	48				30
		E-3	88					25
		I-1	93	53		53		
		I-2	90	50			50	
		I-3	88	48				35
Maximum Duration - Dry Years	Occupied Sites	NA	No Territories	11	5			
		B-3	No Territories	12				6
		D-3	No Territories	12				6
		E-3	No Territories	**7**				12

Measure	SWFL Habitat Class	Alternative	Section					
			Rio Chama	Central	San Acacia			
					LFCC Diversion			
					0 cfs	500 cfs	1,000 cfs	2,000 cfs
		I-1	No Territories	12		6		
		I-2	No Territories	12			6	
		I-3	No Territories	11				5
Maximum Duration - Dry Years	Suitable Habitat <10 miles from Core Areas	NA	1	5	0			
		B-3		5				1
		D-3		5				1
		E-3	1	5				1
		I-1	1	5		1		
		I-2	1	5			1	
		I-3		5				1
Maximum Duration - Dry Years °	Suitable Habitat >10 miles from Core Areas	NA	1	5	5			
		B-3	1	5				11
		D-3	1	5				11
		E-3	1	6				11
		I-1	1	5		5		
		I-2	1	5			5	
		I-3	1	5				11

New Mexico Meadow Jumping Mouse—Impacts to meadow jumping mouse populations are limited to available wet meadow habitat. **Table 4-15** indicates the amount of habitat supported in each section for each alternative. This analysis provides a baseline comparison for the San Acacia Section, as the full range of diversion to the LFCC under No Action was not explicitly evaluated. This table also considered only surface water inundation and not groundwater support for wet meadow habitats. Considering impacts to wetland areas, LFCC diversions near 1,000 cfs supported the maximum wetland habitat areas in the San Acacia Section. Therefore, based on increased wetland habitat support from higher groundwater elevations, it is reasonable to consider that Alternatives I-1 and I-2 may provide the most wet meadow habitat support.

Table 4-15. Acre-Days of Wet Meadow Inundation

Alternative	Acre-Days Wet Meadow Inundation			Sum	% Max	Rank
	Section					
	Rio Chama	Central	San Acacia			
No Action (0 cfs diversion to LFCC)	3	7.3	8.6	18.9	100%	1
B-3	NA	7.3	0.0	7.3	39%	7
D-3	NA	8.4	0.3	8.7	46%	4
E-3	NA	7.0	5.7	12.7	67%	2
I-1	NA	7.4	4.7	12.1	64%	3
I-2	NA	6.8	1.0	7.8	41%	5
I-3	NA	6.8	1.0	7.8	41%	5

Sources of Uncertainty and Data Gaps

Model predictions in the San Acacia Section offer less certainty due to limitations in modeling and highly dynamic and unstable river and riparian environments. Thus, a 10 percent threshold of significance is considered the absolute minimum in this section, with the exception of impacts affecting endangered species in designated critical habitats.

SWFL-occupied habitat within the pool of Elephant Butte Reservoir was not considered in this analysis. Changes in water operations were associated with flood control operations only, not changes in water supply at this Reservoir.

Summary/Comparison by Alternative: Threatened and Endangered Species

Rio Grande Silvery Minnow

The greatest abundance of RGSM habitat occurs in the Central and San Acacia Sections. Potentially suitable habitat was also identified for the Rio Chama Section. Overall, RGSM habitat is best supported by No Action at 0 cfs diversions to the LFCC. All alternatives are either neutral or offer slight improvements to RGSM habitat in the Rio Chama and Central Sections. In the San Acacia Section, RGSM habitat is most directly influenced by diversions to the LFCC. Alternatives I-1 (up to 500 cfs to the LFCC) and I-2 (up to 1,000 cfs to the LFCC) had the smallest impact on RGSM habitat. LFCC diversions up to 1,500 cfs cause the greatest loss of habitat, with slight gains observed once diversions increase to 2,000 cfs. However, slight gains in habitat are observed under action alternatives when compared to equivalent LFCC diversions at No Action at the San Marcial site. Under the same comparisons, slight RGSM habitat losses are observed at the Bosque del Apache NWR site. Of alternatives allowing up to 2,000 cfs diversions to the LFCC, the order of preference in support of RGSM habitat is as follows: E-3, B-3, I-3, and D-3.

Southwestern Willow Flycatcher

Known active SWFL territories have historically been concentrated in the San Acacia Section with lesser occurrences in the other river sections. The SWFL Recovery Plan (FWS 2002b) has established recovery goals for a number of territories and suitable habitat acreage. The suitability of habitat is determined by vegetation, composition, structure, and proximity to surface water.

The SWFL Recovery Plan (FWS 2002) sets a minimum goal of 250 territories for the Rio Grande Recovery Unit needed to warrant reclassification of this subspecies from endangered to threatened. **Table 4-16** shows a comparison of habitat acres by river section compared to Recovery Plan goals (FWS 2002). Only the Central and San Acacia Sections currently exceed Recovery Plan goals. SWFL territories in the

Northern Section appear to meet recovery goals, but the acres of suitable habitat were not mapped in support of this evaluation. The Rio Chama Section is currently below recovery goals in number of SWFL territories and acres of suitable habitat. SWFL territories in the Southern Section were not mapped, so the status of this section with respect to Recovery Plan goals is not known.

Table 4-16. Habitat acres Versus Recovery Plan Goals Per Section for Each Alternative

Habitat Parameter/Alternative	Northern Section		Rio Chama Section	Central Section	San Acacia Section	Southern Section
	River Reaches					
	1, 2	3, 4, 5, 6	7, 8, 9	10, 11, 12, 13	14	15, 16
Known Active SWFL Territories	40-65	12	1	10	149	6
Rio Grande SWFL Recovery Management Unit	San Luis Valley	Upper Rio Grande Unit		Middle Rio Grande Unit		Lower Rio Grande
Recovery Goal Territories	50	75		100		25
Recommended Acres Suitable SWFL Habitat to Meet Recovery Goal	271	407		543		136
Suitable SWFL Habitat in Acres (% mapped)	Not Mapped	172 (5% Reach 4 only)	137 (5% Reach 7 only)	942 (5%)	1374 (7%)	Not Mapped
Acres Suitable Habitat Supported by Alternative[1]						
No Action	Not Mapped		1	18	1,567	Not Mapped
B-3			<1	36	901	
D-3			1	21	797	
E-3			1	39	980	
I-1			1	20	1,570	
I-2			1	19	1,303	
I-3			1	17	810	

Note: [1] Mean annual acres of inundated, suitable habitat less than 10 miles from core areas
Source: Moore and Ahlers 2003; Moore and Ahlers 2004; Stone 2003

All action alternatives would support SWFL Recovery Plan goals in the Central and San Acacia Sections. None of the alternatives are projected to provide adequate acreage of suitable habitat in the Rio Chama Section. There is insufficient data to assess the progress towards recovery goals in the Northern and Southern Sections.

Bald Eagle

The bald eagle is only a winter visitor to reservoirs in the planning area. Bald eagle impact analysis was based on qualitative evaluation of reservoir elevation changes affecting roosting, foraging, and prey base. None of the alternatives are projected to have a significant impact on bald eagle populations in the planning area.

New Mexico Meadow Jumping Mouse

New Mexico meadow jumping mouse habitat in the Rio Chama Section is improved under all alternatives. The meadow jumping mouse habitat in the Central Section is best supported by Alternatives I-1, E-3, and B-3. Wet meadow habitats supported by surface flows in the San Acacia Section were influenced by alternatives with the least diversion to the LFCC (No Action, I-1 and I-2). Qualitative considerations including groundwater elevation analysis suggests that maximal wetland areas are best supported by LFCC diversions between 500 and 1,000 cfs, also favoring the No Action, I-1, and I-2 Alternatives.

Mitigation Measures

Potential mitigation measures for riverine habitat were identified in Section 4.4.2.1. Mitigation measures needed to support overall aquatic habitat would also benefit the RGSM. Additional mitigation measures for RGSM support include the construction of additional in-stream or off-stream habitat to offset any losses incurred under the preferred alternative, continued support for the captive breeding and release programs, and continued rescue and recovery efforts during prolonged channel drying in times of drought.

Mitigation of the adverse effects of the No Action Alternative with 0 cfs diversion to the LFCC on the SWFL is the subject of a 2003 Section 7 consultation with the FWS entitled, "Final Programmatic Biological Opinion on the Effects of Actions Associated with the Programmatic Biological Assessment of Bureau of Reclamation's Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operation, and Related Non-Federal Action on the Middle Rio Grande, New Mexico through February 28, 2013."

The effects of fluctuating reservoir levels at Elephant Butte on the SWFL and their habitat in the flood pool are being addressed separately between Reclamation and the FWS.

No mitigation measures are proposed for the bald eagle.

Mitigation measures for the New Mexico meadow jumping mouse should evaluate support for wetland areas. If an alternative favoring 2,000 cfs diversion to the LFCC is implemented, the change in wetland habitat should be evaluated and, if an adverse impact is observed, increased year-to-year overbank flooding together with targeted supplemental pumping may be needed to provide wet meadow habitat support.

4.4.3 Water Quality

4.4.3.1 Issues

The natural variability of surface water quality within the upper Rio Grande can be attributed to a variety of watershed characteristics and hydrologic processes. These processes include the dynamic balance between the chemical composition of surface water, including tributary inflow and groundwater interaction, precipitation, surrounding geology, nutrient uptake, erosive capability of the channel and surrounding land, and evapotranspiration.

Water quality is further impacted by dams and reservoir operation. Reservoir operations affect water quality by altering water chemistry, natural flow variation, and the transport of sediments, nutrients, and contaminants. Within the Rio Grande watershed, these impacts occur in three primary ways. (1) Reservoirs regulate the downstream flow of sediments, nutrients, and contaminants contributed by groundwater, tributaries, and overland flow sources. Diminished water velocity in reservoirs causes nutrients and suspended sediments to settle, thus decreasing the natural nutrients and sediments in the system. (2) Reservoirs and dams create a unique physical and chemical environment that affects nutrient cycling within the reservoirs, and ultimately may impact riverine environments upstream and downstream of the reservoir. (3) Reservoirs commonly alter the natural temperature regime downstream. Water released from the depths of a reservoir may produce cooler surface temperatures downstream, altering natural conditions that species have become adapted to. Conversely, water released from higher levels in a reservoir may increase surface temperature downstream.

The effects of reservoirs on water quality dissipate as flows continue downstream. With distance from the reservoir, the impacts of tributaries, overland flow, atmospheric conditions, adjacent land use, and surrounding geology on local water quality increase. For example, as water travels downstream after being released from a reservoir, temperature and dissolved oxygen, as well as other constituents, quickly equilibrate with ambient atmospheric conditions. The specific manner in which these changes occur depends on air temperature, storm or snowmelt runoff, land use, and other factors such as turbulence within a river reach.

Water quality resource indicators were identified by evaluating specific water quality constituents most likely to be affected by reservoir operations and the availability of sufficient quality data for analyses. Two reservoirs and 18 USGS gages were selected for detailed water quality analysis. Water temperature, dissolved oxygen, total dissolved solids (TDS)/conductivity, and pH data sets were used for modeling.

4.4.3.2 General Conclusions

There is little difference in the projected impacts on water quality among the action alternatives, except for the No Action Alternative, which ranks last. The only significant impact identified for water quality was reduced dissolved oxygen at Elephant Butte and Caballo Reservoirs, which occurred in all alternatives.

4.4.3.3 Impact Indicators

Impact indicators used to assess water quality include: dissolved oxygen (DO), temperature, TDS/conductivity, and the ability to use conservation storage to modify water quality identified as adaptive flexibility. These indicators were selected based on data availability, data quality, availability of numeric standards, and ability to be influenced by changes in reservoir operations.

Methods of Analysis

The impact of changes in water operations were evaluated by using URGWOM model discharges at the various gages in a series of linear regression models developed to predict water quality changes as a result of dependent and independent variables. Temperature is a dependent variable, discharge, temperature, and reservoir storage were independent variables considered in these equations. Applicable state, tribal, and compact standards were reviewed for each of the five river sections. Boundaries of these reaches were set when a change in water quality regulations or land governance occurred, or when waters entered or left a reservoir. Regression modeling was then used to predict water quality changes based on URGWOM model discharges at the various gages under each alternative. The result was a prediction of the percentage of days where water quality was expected to be in compliance with the appropriate standards.

Thresholds for Significance

The regression equations were developed for a significance level of 0.05; therefore, at least a 5 percent level of error is expected when coupled with the use of URGWOM discharge data at a similar level of error. In general, changes greater than 10 percent were viewed as potentially significant.

Discussion of Results of Analysis

Table 4-17 summarizes the values based on water quality monitoring. A value of 100 percent indicates the best condition; lesser values indicate an unfavorable impact. As modeled, the No Action has the largest adverse impact, especially for temperature along the Rio Chama and the Southern Section reservoirs – Elephant Butte and Caballo. TDS/conductivity is adversely affected in the San Acacia Section. Dissolved oxygen is relatively unchanged. Alternative B-3 provides the best performance with respect to water quality, with slight impacts to temperature and dissolved oxygen in the Central and Southern sections. Alternatives D-3, E-3, I-1, and I-3 all perform similarly, with the largest changes anticipated for dissolved oxygen in Elephant Butte and Caballo Reservoirs. Alternative I-2 performs similarly to the No Action Alternative and ranks sixth of seven alternatives.

Table 4-17. Water Quality Summary

Water Quality Parameter	Section				Total Weighted Score	Water Quality Rank
	Rio Chama	Central	San Acacia	Southern (Elephant Butte & Caballo Reservoirs only)		
No Action						
Dissolved Oxygen	100%	99%	100%	100%		
Temperature	64%	100%	100%	28%	88%	7
TDS/Conductivity	100%	100%	53%	100%		
Alternative B-3						
Dissolved Oxygen	100%	89%	100%	74%		
Temperature	100%	99%	100%	99%	96%	1
TDS/Conductivity	100%	100%	100%	100%		
Alternative D-3						
Dissolved Oxygen	100	94	100	74		
Temperature	89	99	100	100	94	
TDS/Conductivity	100	100	94	100		
Alternative E-3						
Dissolved Oxygen	100%	99%	100%	74%		
Temperature	89%	99%	100%	99%	94%	3
TDS/Conductivity	100%	100%	94%	100%		
Alternative I-1						
Dissolved Oxygen	100%	99%	100%	74%		
Temperature	89%	99%	100%	99%	91%	6
TDS/Conductivity	100%	100%	94%	100%		
Alternative I-2						
Dissolved Oxygen	100%	99%	100%	77%		
Temperature	79%	100%	100%	94%	93%	5
TDS/Conductivity	100%	100%	94%	100%		
Alternative I-3						
Dissolved Oxygen	100%	99%	100%	74%		
Temperature	89%	99%	100%	100%	94%	2
TDS/Conductivity	100%	100%	94%	100%		

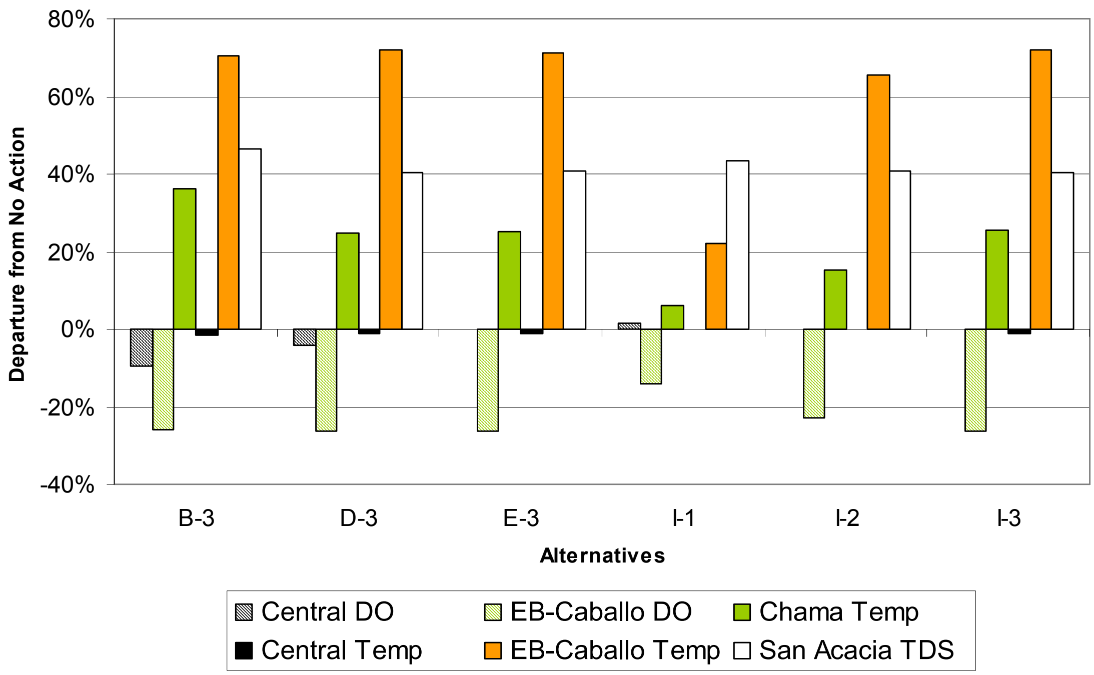


Figure 4-27. Comparison of Water Quality Parameters to No Action

Figure 4-27 shows the departure from the No Action Alternative, with negative values indicating that the No Action Alternative would perform better than the action alternatives listed. Only constituents and sections where differences were identified are included in the graph. The most significant negative departures occurred for dissolved oxygen at Elephant Butte and Caballo Reservoirs.

Sources of Uncertainty and Data Gaps

The current water quality analysis is based on initial regression models that do not explicitly consider flow-based differences in water quality. Further development of annual and daily variations of dissolved oxygen and temperature using statistical modeling and sine/cosine functions is in progress. After accounting for daily and annual variations in these parameters, changes in water quality based on flow will be more thoroughly evaluated. Preliminary indications are that flow-based differences between alternatives are fairly small, especially below the confluence of the Rio Chama and Rio Grande. Therefore, we do not anticipate a significant change in alternative performance. However, the water quality analysis of alternatives will be further updated prior to issuing the Final EIS, with any resulting changes in ranking and alternative preference noted at that time.

4.4.3.4 Mitigation Measures

Significant impacts to dissolved oxygen in Elephant Butte and Caballo Reservoirs occurred with all alternatives. Proposed mitigation measures for water quality provide more oxygenated waters to the reservoir. Mitigation could be accomplished by increasing seasonal discharges of better oxygenated water to the reservoir. This would most easily be accomplished by alternatives providing the most opportunity for upstream native conservation storage and by coordination with other ecosystem mitigation opportunities and Compact water delivery requirements.

4.4.4 Indian Trust Assets and Cultural Resources

4.4.4.1 Issues

Native Americans use the Rio Grande for traditional and cultural purposes. All Pueblos and Tribes are committed to preserving the river and riparian ecosystem; many are implementing habitat restoration projects. Formal government-to-government consultation and informal meetings have identified a variety of concerns related to Indian Trust Assets including water flows, water quality, protection of lands and structures, cultural resources, and support for riparian and riverine habitats.

Cultural resources in the planning area include archaeological sites, historic and prehistoric buildings, potential cultural landscapes, and traditional cultural properties. They are of concern based on various laws including the National Historic Preservation Act, the Archaeological Protection Act, and the Native American Graves Protection and Repatriation Act.

4.4.4.2 General Conclusions

The identification of preferences by individual Pueblos and Tribes is pending. Pueblos and Tribes have been informed about the project through formal government-to-government consultation, coordination meetings with governments from the Eight Northern Pueblos Council, the Ten Southern Pueblos Council, and the Middle Rio Grande Pueblo Water Coalition. Review of impacts specific to Pueblo and Tribal lands is underway.

The preferences regarding Indian Trust Assets (ITAs) reflected in this Draft EIS reflect the opinions provided by cooperating agencies, including the Bureau of Indian Affairs. Alternatives D-3, I-1, I-2, and I-3 were all considered to provide improvements to ITAs including preserving unique and sensitive sites, avoiding impacts to traditional cultural properties, and preserving acequias and other irrigation structures. Alternatives B-3 and E-3, together with the No Action Alternative were considered fair with respect to impacts to ITAs. This analysis will be further refined by ongoing government-to-government consultation.

The area of potential effect was limited to the Rio Chama, Central, and San Acacia Sections. Cultural resources in the Northern and Southern Sections were not affected by proposed changes in operations. Impacts to the San Acacia Section were the greatest, with 55 to 90 percent of sites affected by the alternatives. Alternatives B-3, I-3, D-3, E-3, and I-2 showed improvements over No Action. Alternative I-1 exacerbated cultural resources impacts.

4.4.4.3 Impact Indicators

Current impact indicators are limited to those identified in discussions with the Bureau of Indian Affairs and ID-NEPA team participants from various tribes. Impacts to ecosystem and water quality resources were considered in earlier analyses. Impact indicators in the assessment of ITAs included: preservation of unique and sensitive sites; minimizing impact to traditional cultural properties; preserving acequias and other structures.

Similar impact indicators were used in the evaluation of alternative performance concerning cultural resources preservation. The impact indicators included: number of sites potentially impacted, average duration of inundation over the 40-year period, the degree of channel erosion, and the character of sites affected. This included consideration for the preservation of unique and sensitive sites and preserving acequias and other structures.

Methods of Analysis

Impacts to ITAs and cultural resources were analyzed by similar methods. Based on preliminary evaluation of projected inundation, the area of impact was limited to the Rio Chama, Central, and San Acacia Sections. The number of known sites were identified by reach in each river section. URGWOM and FLO-2D model data were used to identify areas of flooding, inundation, and erosion. The number of sites affected by the degree and duration of inundation was identified for each reach. An analysis of variance was performed to identify significant differences between alternatives. Qualitative assessment was also performed to identify whether certain types of sites were unduly impacted.

Thresholds for Significance

Qualitative analyses were the only analyses performed for ITAs in this Draft EIS. Additional analysis is underway and is subject to refinement pending further information received during the ongoing government-to-government consultation.

Confidence intervals of 5 to 10 percent should be used in interpreting results from cultural resources analysis. No significant differences were observed between alternatives, the range of impacted sites was 383 to 465 among all alternatives, the number of days inundated ranged from 2 to 7 among all alternatives.

Discussion of Results of Analysis

ITAs were evaluated in a qualitative manner based on information provided by the Bureau of Indian Affairs. The No Action Alternative and Alternatives B-3 and E-3 were considered fair in preserving unique and sensitive sites, avoiding impacts to traditional cultural properties, and preserving acequias and other irrigation structures. The remaining action alternatives (D-3, I-1, I-2, and I-3) provided improvements to ITAs over the No Action Alternative. It is expected that this analysis will be refined through ongoing government-to-government consultations.

For cultural resources under all action alternatives, the San Acacia Section has the greatest impacts, with 55 (Alternative E-3) to 90 percent (Alternative I-1) of sites impacted by projected inundation. **Table 4-18** identifies the results of alternative analysis based on projected impacts to cultural resources in all river sections.

Table 4-18. Weighting of Alternatives Based on Impacts to Cultural Resources

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Performance Measure							
Total Sites Inundated	418.0	436.0	383.0	465.0	406.0	406.0	387.0
Percent of Sites Inundated	78.0	81.0	69.0	92.0	73.0	73.0	67.0
Percent of Inundated Sites Eligible for Registry	25.0	20.0	84.0	84.0	24.0	24.0	24.0
Frequency of Inundation over 40-Year Period (years)	1.3	0.6	0.6	0.6	1.3	1.1	0.7
Annual Duration of Inundation (days)	7.0	2.0	2.0	2.0	7.0	4.0	4.0
Score							
Total Sites Inundated	92%	88%	100%	82%	94%	94%	99%
Percent of Sites Inundated	86%	83%	97%	73%	92%	92%	100%
Percent of Inundated Sites Eligible for Registry	80%	100%	24%	24%	83%	83%	83%
Frequency of Inundation over 40-Year Period	46%	100%	100%	100%	46%	55%	86%
Annual Duration of Inundation	29%	100%	100%	100%	29%	50%	50%
TOTAL	333%	471%	421%	379%	344%	374%	418%
RANK	7	1	2	4	6	5	3

Figure 4-28 depicts the estimated number of sites that would be inundated by river section under each alternative.

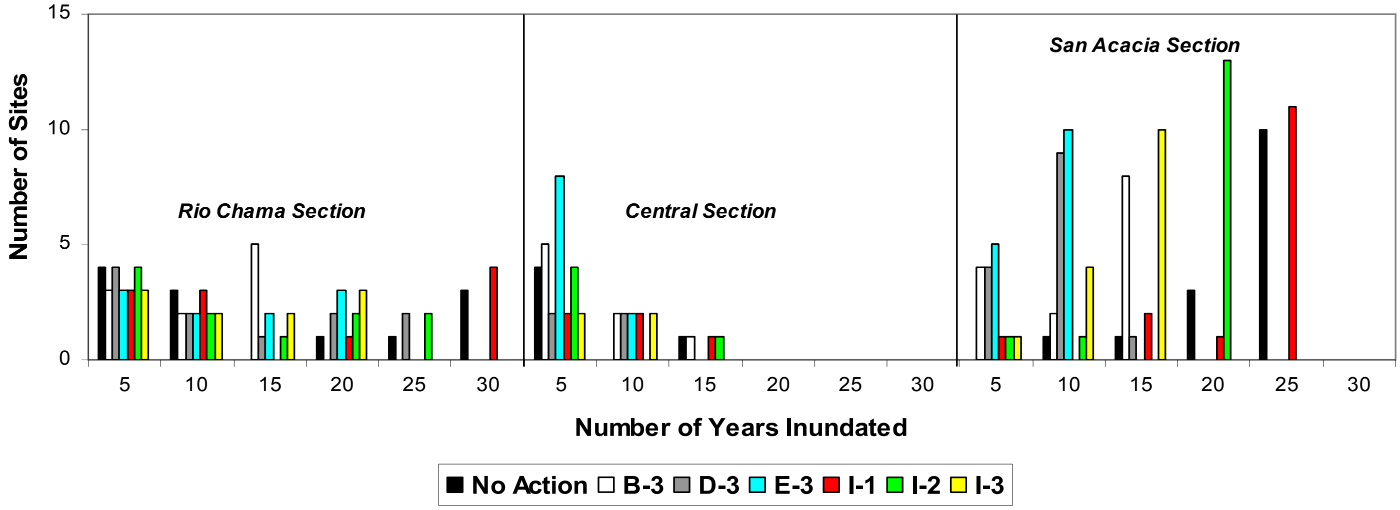


Figure 4-28. Cultural Resources Site Inundation

Sources of Uncertainty and Data Gaps

The propagation of uncertainty and the lack of archaeological surveys in certain river sections are limitations in the analysis of cultural resources. It is estimated that errors of 5 to 10 percent can be expected on analyses founded on URGWOM and other models.

4.4.4.4 Summary/Comparison by Alternative

The No Action Alternative and Alternatives B-3 and E-3 were considered fair in preserving unique and sensitive sites, avoiding impacts to traditional cultural properties, and preserving acequias and other irrigation structures. The remaining action alternatives (D-3, I-1, I-2, and I-3) provided improvements to these indicators that were used to determine impacts to ITAs. This analysis may be refined through government-to-government consultations.

Listed in descending order of preservation of cultural resources, Alternatives B-3, D-3, I-3, E-3, I-2, and I-1 had beneficial effects as compared to the No Action Alternative. While favorable in many respects, Alternatives B-3 and E-3 were projected to have seasonal adverse impacts due to higher channel capacities below Cochiti Dam, primarily related to the preservation of unique and sensitive sites.

4.4.4.5 Mitigation Measures

For *all* the alternatives, site inundation rates are greatest in the San Acacia Section. Between 55 percent (Alternative E) to 90 percent (Alternative I-3) of sites are inundated by all alternatives. The Rio Chama and Central Sections also show elevated inundation rates depending on specific alternatives, albeit at rates considerably lower than for the San Acacia Section.

Therefore, it is anticipated that mitigation measures, *regardless of the preferred alternative that is finally selected*, should focus on preventing overbank flooding in the San Acacia Section. The precise nature of such measures can be determined in consultation with various lead agencies. Depending on the preferred alternative, measures designed to prevent overbank flooding should also be implemented below Abiquiu Dam to the confluence of the Rio Grande in the Rio Chama Section and below Isleta Diversion Dam in the Central Section.

Alternatively, in the event that overbank flooding should emerge as a desired goal of changes in water operations (e.g., for restoration of riparian habitat), mitigation measures might include the construction of barriers. These may take the form of cofferdams or other structures that would prevent or limit overbank flooding of cultural resources.

Finally, if overbank flooding *is* desirable and barriers *cannot* be constructed, it is recommended that archaeological excavations be conducted at those sites where flooding is likely. This mitigation program could be phased so that sites in the greatest danger of flooding would be excavated first, followed–in order–by excavations at sites that are progressively less subject to overbank flooding.

4.4.5 Agriculture, Land Use, and Recreation

4.4.5.1 Agriculture

Issues

Agricultural activity in the Upper Rio Grande basin would continue, subject to the existing plans and regulations for water operations and expected water deliveries to irrigators. It is assumed that current crop types, acreage, cropping patterns and trends would continue.

Impacts to delivery of water to irrigators and growers and impacts to acequia diversion structures are assessed under each alternative. Inundation is another key criteria evaluated because crops could be damaged or destroyed by flooding, depending on the timing and duration of the flood event. Diversion structures can also be overtopped, typically requiring maintenance and repair after high flow events.

General Conclusions

The potential to impact agricultural activities was identified within a 5-kilometer buffer on either side of the Rio Chama and Rio Grande. Changes in water operations have the potential to affect agricultural lands in the Rio Chama, Central, and San Acacia Sections. The Northern Section is not affected by proposed operational changes. The Southern Section did not invoke flood control operations that would result in any impacts from proposed operational changes.

Based on the impact analyses performed, Alternative B-3 is the most favorable for agricultural uses, with the greatest benefits observed in the Rio Chama Section due to decreased channel capacities below Abiquiu. Alternatives I-3, E-3, D-3, and I-2 provide improved support for agriculture when compared to No Action. Alternative I-1 provides less support for agriculture, especially along the Rio Chama due to increases in the acres and duration of inundation, the number of overtopping events. All alternatives provide the same level of support for irrigation water deliveries in the Central and San Acacia Sections.

Impact Indicators

The review for agricultural resources evaluates whether operational actions could change conditions needed to support the type, extent, and quantity of agriculture currently practiced within the Upper Rio Grande Basin. This analysis is primarily concerned with identifying distinguishable differences between the alternatives for key issues that directly affect agriculture in the Basin. These include:

- Impacts to delivery of water to irrigators and growers (Central and San Acacia sections)
- Impacts to acequia diversion structures (Rio Chama section)
- Loss of viable agricultural land and crops through inundation
- Loss of or reduced productivity of agricultural lands due to saturated soil conditions (Rio Chama)

Methods of Analysis

The analysis relies on summarized outputs from URGWOM and FLO-2D to make broad comparisons using the following measurable criteria:

- Average seasonal shortfall in meeting irrigator water requests; number of years with shortfalls; number of days with shortfalls
- Number of days when diversion elevation are exceeded by river elevation
- Extent and duration of inundated agricultural land (Reaches 7, 8, 9, 12, 13, 14)
- Frequency of prolonged "bankfull" flows (Reach 7)

Thresholds for Significance

The estimates for agricultural impacts rely on the URGWOM and FLO-2D data and are therefore subject to the same 5 to 10 percent level of error in the evaluation of results for significant changes.

Discussion of Results of Analysis

Table 4-19 shows alternative performance for agricultural impact indicators along the Rio Chama, Central, and San Acacia Sections. Alternative B-3, with a reduced channel capacity below Abiquiu Dam, decreases inundation and diversion overtopping events, while maintaining the same level of support for irrigation season deliveries in the Central and San Acacia Sections. All other alternatives, except I-1, perform worse than the No Action Alternative for agricultural measures.

Over the 40-year planning period there would be no significant difference in the average annual seasonal shortfall in deliveries to irrigators in the Central Section compared to the No Action Alternative. Agricultural lands in the Central and San Acacia Sections were not projected to be inundated at any time during the planning period, in part due to the protection assumed by the levees.

Table 4-19. Agricultural Impacts by Alternative

	Rio Chama				Central & San Acacia Sections
Alternative	Total Acres Inundated over 40-year Period	Duration of Inundation (acre-days)	Number of Events Where Diversions Overtopped	Extended Bankfull Events >1,500 cfs for >7 days	Average Irrigation Season Shortfall (%)
No Action	692	1,736	219	33	32
B-3	126	4,970	174	0	32
D-3	673	32,847	199	20	32
E-3	507	24,016	210	19	32
I-1	694	39,123	225	32	32
I-2	592	30,643	214	27	32
I-3	488	23,903	210	19	32

Table 4-20 indicates that over the 40-year planning period there would be no significant difference in the average annual seasonal shortfall in deliveries to irrigators in the Central and San Acacia Sections compared to the No Action Alternative. The No Action Alternative would perform slightly better on average than the other alternatives in meeting delivery requests, but the advantage would be minimal. The greatest shortfall would be 32 percent (only about 0.5 percent higher than under the No Action Alternative) and would occur under Alternative I-3. There would be no real difference in the percentage of delivery days where shortfalls are estimated over the 40-year planning period.

Table 4-20. Average Annual Seasonal Shortfall to Irrigators in the Central Section over 40 Years

Alternative	Average Irrigation Season Shortfall (%)	40-Year Average Annual Seasonal Shortfall (acre feet)			
		Cochiti Diversion	Angostura Diversion	Isleta Diversion	San Acacia Diversion
No Action	32	0.2	8	62	16
B-3	32	0.1	8	62	16
D-3	32	0.2	8	63	16
E-3	32	0.2	8	62	16
I-1	32	0.2	8	62	16
I-2	32	0.2	8	63	16
I-3	32	0.2	8	63	16

Source: Derived from URGWOM Planning Model Runs

Sources of Uncertainty and Data Gaps

The agricultural land use analysis did not include evaluation of impacts to Pueblo and Tribal lands. The review is limited to operations that may affect less than 30 percent of the agricultural land in the Upper Rio Grande basin – about 53,000 acres along the Rio Chama, Central and San Acacia Sections. Other sections and reaches that are outside the influence of operations within the authority of this review and decision are not further evaluated, including the Northern Section, Reach 5 in the Rio Chama Section, Reach 11 in the Central Section, and the Southern Section. Several existing agreements ensure water needs for irrigators along the Rio Chama are met; therefore, issues in this section revolve around performance of the diversion structures, soil saturation, and inundation. In the Central Section, the demand schedule for irrigators below Cochiti was assumed to be the same as current demands over the next 40-years.

Delivery of irrigation water to tribes and pueblos is provided as one of the non-discretionary operational criteria and therefore would not vary between alternatives. The impact of drought on deliveries to tribes is beyond the scope of this evaluation. The difference in impacts between the alternatives from inundation of agricultural lands on pueblos may be similar to the effects reported for all inundation. Based on this, inundation of agricultural lands on pueblos may be slightly less extensive under the No Action.

Summary/Comparison by Alternative

Based on impact analyses, Alternative B-3 is the most favorable for agricultural uses, with the greatest benefits observed in the Rio Chama section. All other alternatives perform slightly worse for agricultural support in the Rio Chama than No Action. All alternatives provide the same level of support for irrigation water deliveries in the Central and San Acacia Sections.

Mitigation Measures

No mitigation measures are currently proposed for projected impacts to agricultural lands. However, in the event Alternatives I-1 or D-3 are selected as the preferred alternative, consideration for minimizing potential damages due to increased channel capacity below Abiquiu Dam (D-3) or reduced (20,000 AF) conservation water storage capacity in Abiquiu (I-1) are exercised.

4.4.5.2 Land Use

Issues

Much of the land in the project area is undeveloped. However, other land uses in the area include residential, commercial, industrial, transportation, communications and utilities, agricultural, institutional, and recreational. Primary concerns that could affect land use include:

- Maintaining reliable water delivery for agricultural, municipal and industrial purposes
- Public safety and flood control
- Damage to property and productive uses from inundation
- Land conversion from agriculture to developed use
- Impacts of flooding on specially managed areas and recreational opportunities

General Conclusions

All action alternatives perform better than No Action in promoting desirable land uses for agriculture, recreation, and minimizing property damage.

Impact Indicators

Three overall criteria were assessed for desirable land uses:

- Degree to which an alternative promotes recreational use
- Degree to which an alternative preserves suitable conditions for agriculture
- Degree to which damage to property or loss of productive uses is minimized

Methods of Analysis

The criteria listed above were derived from the impact analyses specific to the three land use criteria considered: recreation, agriculture, and flood damages.

Thresholds for Significance

At least a 10 percent change was required to identify a significant impact, based on the sources of error and uncertainty in the underlying gage data, URGWOM and FLO-2D models, and GIS database.

Discussion of Results of Analysis

Overall, periodic inundation immediately along the river would not alter land use patterns that have evolved in response to periodic flood events and controls on development in floodplains. Occasional inundation would occur within the historic floodplain over the 40-year planning period, as verified by the FLO-2D model. These inundated areas are either undeveloped, or used for agriculture, grazing, and dispersed recreation.

With no diversion into the LFCC under the No Action Alternative, the San Acacia Section would experience the highest amount of inundation (about 2.8 million acre-days over 40 years). However, none of the projected inundation would occur on agricultural land, and only one residential structure encroaching on the floodplain is projected to be at risk.

Coordination between county planning and permitting officers is intended to limit encroachment into floodplains and flood easements in order to protect public safety and preserve flexibility for water operators. Similarly, management and control of private development in flood easements, particularly around Abiquiu Lake, would prevent encroachment and enhance flexibility for water operations to meet multiple objectives.

Sources of Uncertainty and Data Gaps

Land use impacts were identified for non-Tribal lands in the planning area. Tribal land impacts were evaluated in consideration of Indian Trust Assets and may be further modified during government-to-government consultation.

- The analysis is limited to the Rio Chama Section (Reaches 6, 7, 8, 9), the Central Section (Reaches 10, 12, and13), and the San Acacia Section. The Northern and Southern Sections are not influenced by operations under the authority or review of this effort. Operations for flood control (below Elephant Butte reservoir) did not vary between alternatives.
- Operations will not cause changes in overall land status and ownership.
- All levees function adequately and areas protected by levees will not be inundated.

Summary/Comparison by Alternative

Table 4-21 summarizes overall performance on the three impact indicators identified above. All action alternatives perform better than No Action in supporting the varied land uses in the basin. Alternative I-3 provides the best balance among varied land uses, while Alternative B-3 best supports agriculture. Alternative E-3 is similar to I-3 in support of recreational uses, and Alternative D-3 is similar to I-3 in minimizing flood damages.

Table 4-21. Desirable Land Use Performance

Criteria	No Action	Alt B-3	Alt D-3	Alt E-3	Alt I-1	Alt I-2	Alt I-3
Minimizes flood damages	6.6	9.0	9.8	8.6	7.4	8.8	9.8
Promotes Recreation	5.3	5.6	5.9	6.0	5.0	5.5	6.0
Promotes agriculture	7.7	8.3	6.6	7.9	7.6	7.7	7.9
Total score	19.6	22.9	22.3	22.5	20.0	22.0	23.7

Mitigation Measures

No mitigation measures are proposed for land use impacts.

4.4.5.3 Recreation

Issues

Reservoir recreation is affected by proposed changes in the various water operations alternatives. Current operations reflect the challenges from recent drought-induced low lake levels. Measures have already been implemented at key recreation sites to add new boat ramps and improve boat access as lake levels change. Facility managers consider the “safe boating capacity” of the lake or reservoir in terms of surface area per boat. At Elephant Butte, where recreation is by far the greatest of any reservoir in the planning area, the possible number of boats at the reservoir is limited by the number of mooring slots and tie-up points for boats. Based on average reservoir water levels (and surface areas) and maximum boat numbers, the ratio of acres per boat is well above generally accepted safe boating standards (BLM 1999). While this is not currently an issue, setting standards at each reservoir based on the type of boating allowed and the experience desired would be a beneficial safeguard for maintaining safe and high quality boating opportunities.

River-based recreation takes place at key locations where facilities have been developed and in areas where the public has access, primarily to publicly-owned land. Most facilities are beyond the zone of inundation, but some trails, picnic areas, and campsites along the river may be subject to occasional flooding. Like reservoir use, visitation to developed recreation sites is heavily influenced by a variety of factors including proximity to urban areas, availability of recreational alternatives, access to river-side facilities and put-in locations, vandalism and sense of safety for visitors, weather, and restrictions such as forest closures.

Through informal agreements, water operators currently time the release of water to meet desired flows of 1,000 cfs on weekends during the rafting season, as rafting activities requires certain minimal flows. However, factors that have no relation to water operations have a significant effect on rafting. For example, during some years, rafting operations ceased when access to put-ins on public land were restricted due to fire hazard conditions. However, specific releases to support rafting were not explicitly modeled for the evaluation of alternatives.

Fishing on the Rio Chama and Rio Grande depends on suitable conditions for high quality fisheries, and for flows that are conducive to safe fishing, particularly for in-stream anglers. Other pressures, such as overcrowding at favorite fishing spots, could impinge on the quality of the experience over time. In general, fish stocking practices by the NMDGF would continue to maintain a reasonable supply of fish for recreational purposes. The relative frequency of days with flows that are suitable for fishing at selected popular fishing locations is an important criterion used for evaluating fishery quality.

Conflicts can occur between recreational uses along the same river reach. For example, minimum flows for rafting on the Rio Chama below El Vado and Abiquiu Dams are 500 cfs during the April 1 through September 15 rafting season. Whereas anglers require flows conducive to safe fishing—for example, below Abiquiu, suitability is determined by flows in the range of 50 to 300 cfs between May 1 and October 1. One of the goals of this Draft EIS is to minimize conflicts and provide better opportunities for the varied users in the river system.

General Conclusions

River- and reservoir-based recreation would be affected by changes in water operations in the Upper Rio Grande basin. However with respect to recreation, all the action plans would result in improved conditions in comparison to No Action, with Alternative B-3 offering the largest potential overall gains in access. Alternatives B-3 and D-3 offer the most opportunity to satisfy the needs of recreational users with conflicting requirements (i.e., anglers vs. rafters).

Impact Indicators

Impact indicators for reservoir recreation were based on days of access provided by suitable lake elevations. Impact indicators for rafting considered the number of days less than the 500 cfs desired minimum flows on the Rio Chama below El Vado and Abiquiu Reservoirs. Angling suitability was evaluated based on the number of days with suitable fishing flows at selected fishing spots along the Rio Chama below El Vado and Abiquiu Reservoirs.

Methods of Analysis

Because of the variability of water-based recreation, the analysis focuses on qualitative effects rather than on estimating changes in visitation or use. Criteria selected are representative and generally only apply to some reaches or facilities. These measures are comparative indicators to assess the degree to which the alternatives may promote suitable conditions for recreation. URGWOM model data were used to obtain reservoir elevations and flows at key gages along the Rio Chama to support this analysis.

Thresholds for Significance

As with other resources using data from gages, models, and the GIS database, at least a 10 percent change from No Action was considered as signifying a potentially significant impact.

Discussion of Results of Analysis

Table 4-22 summarizes the number of days over 40 years when water levels would be unsuitable for access to facilities based on indicator levels provided by reservoir personnel (Casados 2001; Dunlap 2001; Corps 2001c, d). Current management of facilities under the No Action Alternative would be less beneficial than under the other alternatives. Current operations and visitation reflect the challenges from recent lower lake levels. For example, at Elephant Butte Reservoir, the most visited lake in the planning area, new boat ramps have been added to provide access for boats as lake levels change. This evaluation does not take into account these new facilities.

Table 4-22. Access for Water-based Activities at Reservoirs

Alternative	Days When Lake Elevation Impairs Access (%)			
	Heron Lake	Abiquiu	Cochiti	Elephant Butte
No Action	29	88	1	12
B-3	31	65	<1	0
D-3	29	70	<1	0
E-3	29	69	<1	0
I-1	29	86	<1	6
I-2	29	78	<1	<1
I-3	29	69	<1	0

Notes: Critical (unsuitable) elevations:
Heron Lake—less than 7,136 feet (Casados 2001)
Abiquiu Reservoir—less than 6,202 feet (Dunlap 2001)
Cochiti Lake—less than 5,317 feet or greater than 5,370 feet (Corps 2001d)
Elephant Butte—less than 4,400 feet (Kirkpatrick 2001)
Source: Derived from URGWOM (40-year, daily reservoir elevations)

Table 4-23 shows that under the No Action Alternative, flows would fall below 500 cfs—the preferred minimum level on the Rio Chama between El Vado and Abiquiu—on 52 percent of the days during the rafting season over the 40-year planning period. Rafting would benefit from formalized agreements to the extent that this does not conflict with meeting other priorities or contract obligations. It should be noted that during some years, rafting operations have ceased when access to put-ins on public land were restricted due to fire hazard conditions.

Table 4-23. Suitability[1] for Rafting on Rio Chama between El Vado and Abiquiu

Alternative	Days <500 cfs over 40-years2, 3 (#)	Suitable Rafting Days (%)
No Action	3,435	48
B-3	3,344	49
D-3	3,356	49
E-3	3,444	47
I-1	3,428	48

Alternative	Days <500 cfs over 40-years2, 3 (#)	Suitable Rafting Days (%)
I-2	3,433	48
I-3	3,444	47

Notes: 1. Unsuitable rafting conditions indicated when flow rate is less than 500 cfs.
2. Based on rafting season from April 1 through September 15.
3. Estimated for gage below El Vado
Source: Derived from URGWOM Planning Model runs

Table 4-24 shows the relative frequency of days with flows that are suitable for fishing at selected popular fishing locations. There is little difference between alternatives on conditions along the Rio Chama below El Vado. The Rio Chama below Abiquiu Dam has the most variation with the No Action Alternative being the least favorable.

Table 4-24. Suitability for Anglers at Selected Locations on Rio Chama

Alternative	Days with Suitable Fishing Flows over 40-year Planning Period (%)	
	Rio Chama Section below El Vado Dam	Rio Chama Section below Abiquiu Dam
No Action	71	21
B-3	71	38
D-3	72	38
E-3	70	38
I-1	69	26
I-2	69	33
I-3	70	38

Notes: 1. Suitability >190 cfs and <830 cfs at gage below El Vado between May 1 and October 1.
2. Suitability >50 cfs and <300 cfs at gage below Abiquiu between May 1 and October 1.
Source: Derived from URGWOM Planning Model runs

Sources of Uncertainty and Data Gaps

Analysis of recreation resources was affected by relatively coarse datasets or lack of detailed information that required broad, mostly qualitative analyses. Data were provided in inconsistent formats from one river section to another, making comparisons difficult. For this reason, data quality was mostly rated fair, indicating the need for more uniform data collection of recreational uses of reservoirs and rivers along the Rio Chama and Rio Grande corridors to improve future analyses.

Summary/Comparison by Alternative

Reservoir-based recreation is best-supported by Alternative B-3. All alternatives result in some impaired recreational access at Heron Lake and Abiquiu Reservoirs – largely a function of hydrology. However, improvements over No Action are realized with increased conservation storage in Abiquiu Reservoir. While Alternative B-3 shows slightly less access at Heron Lake, access to Abiquiu Reservoir is improved. Recreational access to Cochiti is not affected by any of the alternatives. Recreational access to Elephant Butte would be significantly impacted only under No Action (12 percent), while Alternative I-1 would potentially reduce access 6 percent of the time. Overall, No Action provided the least support for reservoir recreation, while Alternatives B-3, E-3, and I-3 were the three top-ranked alternatives for this resource.

River recreation is a primary activity along the Rio Chama Section, and is only incidental in the Central and San Acacia Sections. River recreation in the Northern and Southern Sections was not subject to impacts from changes in water operations. Rafting suitability along the Rio Chama between El Vado and Abiquiu is best supported by Alternatives B-3, D-3, and I-1. Angling activities along the Rio Chama are best supported by Alternatives D-3, B-3, E-3, and I-3. Thus, for riverine recreation, Alternatives B-3 and D-3 offer opportunities to best satisfy multiple users with conflicting requirements.

Overall, recreation along the upper Rio Grande is better supported by all action alternatives when compared to No Action. Alternative B-3 best supports all forms of river and reservoir recreation. Alternatives D-3, E-3, and I-3 rank in the top tier, with Alternatives I-2, and I-1 offering lesser support for recreational activities.

Mitigation Measures

Mitigation measures already employed by recreation facility managers at the reservoirs and lakes include the extension of boat ramps to accommodate access during times of low lake levels, and promotion of alternative shore-line activities when lake surface areas are low. It is expected that similar measures would be implemented by these same recreation facility managers as hydrologic conditions and reservoir storage change. Projected conditions are presented to the public annually in April, in conjunction with preparation of the Annual Operating Plan.

Rafting would benefit from formalized agreements to the extent that this does not conflict with meeting other priorities or contract obligations. It should be noted that, during some years, rafting operations have ceased when access to put-ins on public land were restricted due to fire hazard conditions.

Stocking fish would continue in the future and partially offset any adverse impacts on reproduction of native fish. No significant changes to sport fishing at reservoirs would result. Therefore, recreational reservoir fishing would follow the same patterns and trends that have been experienced in the past

4.4.6 Flood Control

Issues

There have been no property damages sustained nor anticipated from direct releases by the flood control facilities under consideration by this EIS. However, residual flood damages from unregulated drainages could occur depending on flows. Evaluation of alternatives, therefore, focuses on changes in residual flood damages associated with the proposed operation changes. The affected environment includes the current flood control structures and benefits, as well as the areas that remain threatened by floods.

Total flood control benefits from Corps projects along the Rio Grande and its tributaries since their inception through 2002 have totaled over $1 billion (Corps 2003: 36-1-36-10). In addition, significant damages from river sedimentation are also prevented. Other projects along the Rio Grande have prevented significant flood damages as well. These include Elephant Butte/Caballo, El Vado, the International Water Boundary Commission levees on the Rio Grande, and numerous dams constructed by the Natural Resources Conservation Service.

Operational changes proposed under the action alternatives have the ability to affect only the Rio Chama, Central, and San Acacia Sections. While the Northern Section has sustained damages from flows along the Rio Grande Mainstem, no changes are proposed, thus impacts resulting from water operations were not evaluated. Similarly, flood control operations at Elephant Butte and Caballo Reservoirs were not triggered by the 40-year modeling analysis, thus no impact analysis was performed in the Southern Section.

General Conclusions

With respect to flood control, all action alternatives offer improvements over No Action. Alternatives B-3, D-3, E-3, and I-3 offer the most protection, with varying degrees of improvement along the Rio Chama. Alternatives B-3 and E-3 project additional flooding potential near Belen due to the higher channel capacities below Cochiti, where Alternatives D-3 and I-3 offer greatest reduction in flooding of the San Acacia Section. Alternatives I-1 and I-2 offer lesser levels of improvement, as they reduce the amount of conservation water impounded upstream in Abiquiu Reservoir.

Impact Indicators

URGWOM daily stream gage flow projections were retrieved to estimate flooding at locations near damage centers identified above for the No Action and action alternatives. Each damage center has a flow-damage relationship, and has a maximum flow that can pass without creating property, called the “start of damages”. Each day over the analysis time frame that a stream gage flow was equal to or greater than the start of damages flow for a given damage center was identified for each alternative. Alternatives that create more days over the project life where flows exceed the start of damages can be said to be increasing damages, and would be less desirable than those with equal or fewer total days where flooding exceeds the start of damages. In the following tables, this measurement was termed “Days Flooded.”

Another measure of alternative impacts is an estimate of the dollar damages over the project life cycle, generated by interpolating the flows for each day to the flow-damage relationships available, and then generating a grand total over the project life cycle. No estimates of growth within the floodplain are available, and the flow-damage relationships used are current as of their stated price level. No discounting of future benefits was performed to bring the price levels across damage centers in line, and the damages represent nominal damages, in thousands of dollars, at the price level indicated on the flow damage relationship for that damage center.

Methods of Analysis

The hydro-economic model used to develop expected annual damages is based on discharge-frequency, stage-frequency, and stage-damage curves used to develop a damage-discharge curve. Stage-percent damage curves express dollar damages resulting from varying depths of water based on a percentage of the value of structure and contents.

Each surveyed property was assigned to a category (e.g., commercial, residential, public, outbuilding, transportation facilities, utilities, and vehicles) with as many subcategories as necessary. Details of ground and first floor elevations were also noted. The depth-damage relationship for each category was expressed as a cumulative percentage of value for each foot of inundation. The depth-damage relationships were derived from historical data obtained from insurance companies, a commercial content survey, the Flood Insurance Administration, and Corps data and experience. Note that the 2001 residential curves developed by the Institute of Water Resources (IWR) were used; thus, the residential content damages are a direct relationship to structure value.

Value of Property: A survey of structures within the floodplain was conducted to evaluate the flood threat to each damage center. Property categories surveyed include residential, commercial, public buildings, vehicles, transportation facilities, utilities, and outbuildings (e.g., sheds and detached garages). Depreciated, replacement residential structure values were computed using local experts such as realtors, appraisers, and builders. The properties were then compared to actual sales data in the area and field inspected for consistency and first floor elevations.

Content values were estimated from several sources. Residential content values were fixed at 50 percent of the structure value. Generally, property insurers estimate content values at greater than 55 percent of structure value. Commercial and public content values were estimated primarily from surveys of similar establishments and interviews.

Vehicle estimates were determined using in-house data and published surveys. It is assumed that all business-related vehicles would have been evacuated from the floodplain. Therefore, the vehicles that would remain in the floodplain would be associated with residential structures and apartments. Census data or locally available information was used to determine the per capita vehicles per household. It was assumed that one of these vehicles per household was driven out of the floodplain. The remaining vehicles will be distributed among the residential structures located within the 0.2 percent chance exceedance floodplain.

Potential flood effects occur at all the locations listed below. In addition, there are several areas along the Rio Grande that have not experienced flooding recently, but as a result of the deterioration of a nonengineered levee or other facilities, are prone to flooding at under certain flow conditions. These areas include Española, from Bernalillo to Belen, and from San Acacia to Elephant Butte. All of these areas are currently being analyzed in studies by the Corps.

For purposes of currently available flood control analysis the Rio Grande and Tributary floodplains are broken down into several reaches:

- The upper reach is comprised of the Rio Grande as it flows through Colorado, primarily centered upon Del Norte, Monte Vista, and Alamosa
- The next reach is comprised the area from Pilar, New Mexico through Española
- The third reach is the Chama Valley from Abiquiu to the Rio Grande
- The fourth reach is from Bernalillo to Belen
- The fifth reach is from San Acacia to Elephant Butte
- The sixth reach is in Hudspeth County to the east of El Paso. Other areas that do not currently have flood control analysis have the potential for damages. These include the area from Elephant Butte through El Paso, several points on the river north of Bernalillo, Mexico, and the area east of Fort Quitman

Information regarding damages to Mexico is currently not available. Most damages in this reach are not readily converted into a damage-flow curve, because many occur from a rise in groundwater rather than direct overflow.

Thresholds for Significance

As discussed for other resources, a minimum change of 10 percent from No Action was considered to be the threshold of significance for identifying significant changes in performance between alternatives. This threshold considers the propagation of errors associated with input data, modeling, and spatial analyses.

Discussion of Results of Analysis

A summary of days of flooding and projected damages by alternative is provided in **Table 4-25**.

Table 4-25. Flooding and Projected Damages by Alternative

Alternative	Rio Chama Section				Central Section				San Acacia Section	
	Below Abiquiu to Confluence		Confluence to Espanola		Corrales		Belen		San Acacia	
	Days Flooded (Days)	Damages (Dollars)	Days Flooded (Days)	Damages (Dollars)	Days Flooded (Days)	Damages (Dollars)	Days Flooded (Days)	Damages (Dollars)	Days Flooded (Days)	Damages (Dollars)
No Action	1000	$5,000	300	$200,000	120	$3,100	0	$0	200	$4,300,000
B-3	340	$1,300	260	$152,000	88	$6,500	46	$36,000	56	$1,054,000
D-3	710	$4,100	280	$175,000	100	$7,000	0	$0	6	$5,400
E-3	610	$2,800	270	$160,000	100	$8,200	52	$53,000	64	$1,462,000
I-1	987	$4,800	301	$200,100	120	$800	0	$0	188	$3,228,000
I-2	770	$3,600	280	$183,000	100	$700	0	$0	140	$1,400,000
I-3	620	$2,800	270	$166,000	100	$650	0	$0	6	$53,000

Under the No Action Alternative, flood control reservoirs—Abiquiu and Cochiti—would reduce flood peaks and continue to provide flood control benefits to downstream areas. Periodic flooding and damages from unregulated drainages would continue to occur over the 40-year period. No Action has the highest number of days flooded and highest total dollars in damage projected over the 40-year period. With the lower channel capacity below Abiquiu, Alternative B-3 provides the best overall performance and largest improvements in the Chama Section. However, with the higher channel capacities below Cochiti, both Alternatives B-3 and E-3 increase the potential for flood damages in the Central Section near Belen. Due to the levee system near Albuquerque, no flood damages were observed under any alternative. Alternatives D-3 and I-3 provide similar reductions in flooding, with the greatest changes observed in the San Acacia Section. Alternatives I-1 and I-2 perform only slightly better than No Action.

Sources of Uncertainty and Data Gaps

Corps hydraulic engineers developed floodplains and event stages for specific frequency flood events, as well as the single occurrence damages associated with each event. Some of these studies predate new GIS-related tools so data other than the flow-damage relationship is unavailable. Note that some growth may have occurred since the initial study, and further growth is expected, such that the damages associated with specific frequency events will be higher than indicated.

Future development would change potential damages from any flood event. While future population estimates in the planning area are important, the quantity of that development that occurs within the floodplain is the relevant aspect and is a rough estimate at best. Note that any future development that occurs should follow Federal Emergency Management Agency (FEMA) requirements and be elevated to the 100-year flood event.

It should also be noted that the analysis for No Action was performed under zero diversions to the LFCC, potentially impacting the evaluation of flooding potential in the San Acacia Section. Under diversions to the LFCC, it is expected that No Action would perform similarly to I-1 for 500 cfs diversions, I-2 for 1,000 cfs diversions, and I-3 for 2,000 cfs diversions.

Summary/Comparison by Alternative

Figures 4-29 to 4-31 summarize the change from No Action under each alternative by the three affected river sections, Rio Chama, Central, and San Acacia. All action alternatives offer improvements in flood control over the No Action condition. Detailed information by reach is provided in Appendix P-3.

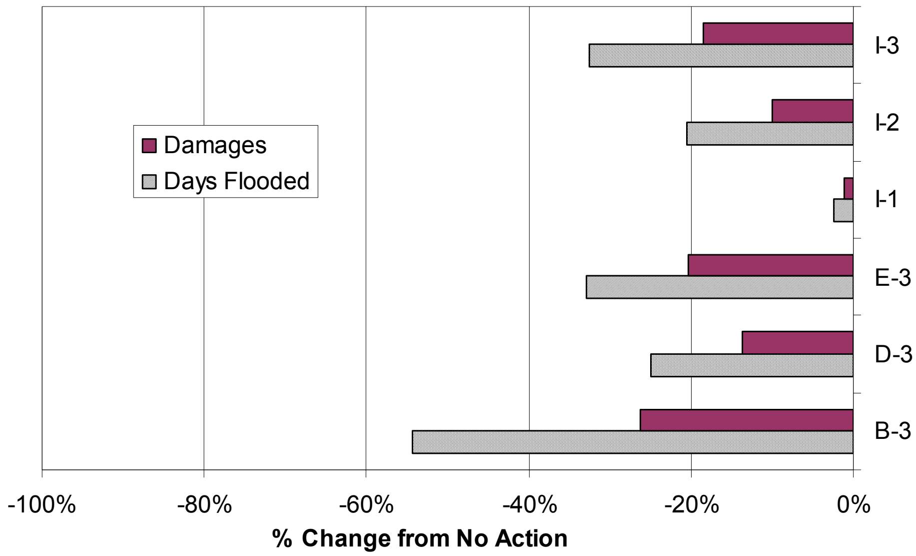


Figure 4-29 Days Flooded and Projected Damages in Rio Chama Section

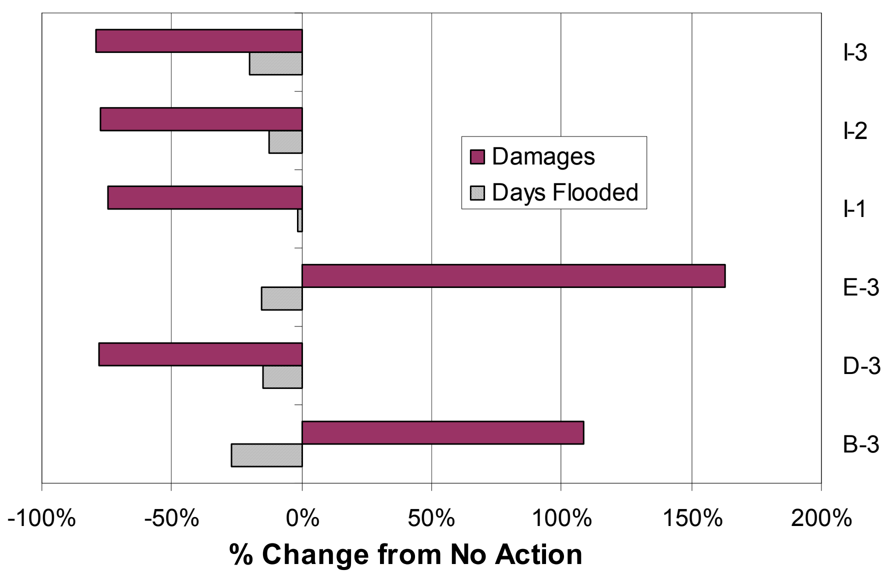


Figure 4-30. Days Flooded and Projected Damages in Central Section

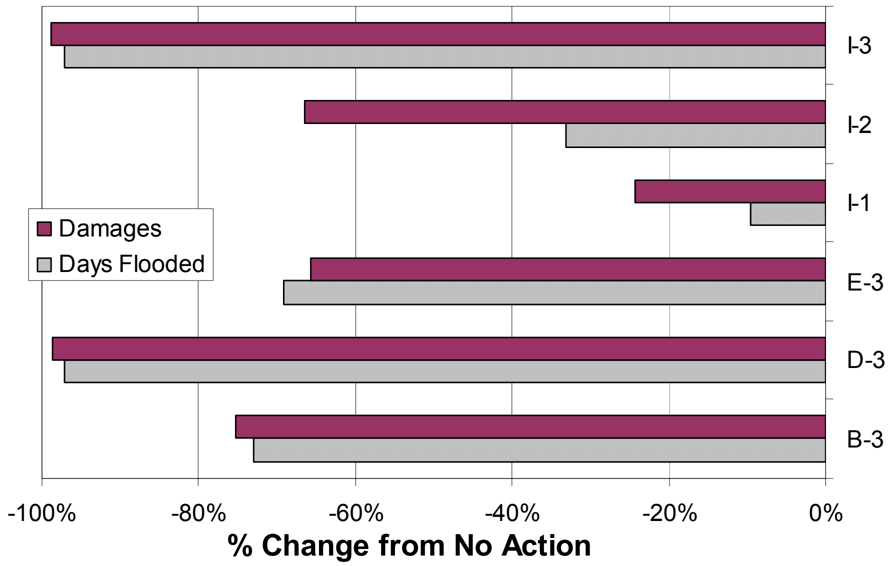


Figure 4-31. Days Flooded and Projected Damages in San Acacia Section

Mitigation Measures

No mitigation measures are proposed at this time for any damages related to flooding, as all alternatives show improvement over No Action.

4.4.7 Hydropower

Issues

Hydropower production is impacted by storage regulation and water allocation among the various reservoirs in the Rio Grande Basin. Hydropower production facilities include El Vado, Abiquiu, and Elephant Butte Reservoirs. The first two facilities are located on the Rio Chama, while Elephant Butte Reservoir is located in the Southern Section of the Rio Grande near the city of Truth or Consequences. Changes in operation will affect the total power generation at these plants.

General Conclusions

All alternatives produce additional output at Abiquiu and Elephant Butte Reservoirs as compared to No Action. However, all alternatives also marginally decrease energy production at El Vado Reservoir, but the additional output at Abiquiu and Elephant Butte Reservoirs more than make up for this loss.

Alternatives I-3, E-3, and D-3 result in an almost $3.0 million projected increase in hydropower revenues over No Action. Alternatives I-2, I-1, and B-3 provide the second tier in performance, with incremental increases ranging from $1.4 to $2.7 million over the No Action Alternative.

Impact Indicators

There are two components to hydropower benefits. The first, the capacity benefit, is associated with investment costs that would be displaced by the additional hydro generation. The capacity benefits are based on the dependable capacity of the hydro plant and a unit capacity value based on the fixed costs of the most likely thermal alternative. A significant impact would be a material increase or decrease in the capacity benefit.

The second component is the energy benefit. This measures the displaced variable costs and is the cost of energy that would be produced from other generation sources if the hydropower is not available;

specifically, the cost of generation from the area power plants that would most likely provide the replacement generation (or would be displaced by additional hydro generation). These energy costs are primarily fuel costs, along with some variable operations and maintenance and transmission costs. Energy benefits are computed as the product of the average annual energy and unit energy value which represents the average cost of replacement generation. A significant impact would be a substantial increase or decrease in the energy benefits provided by an alternative considered.

Methods of Analysis

Hydropower values on the dams are computed differently. The El Vado and Abiquiu plants are used primarily to displace thermal energy and are not considered to have dependable capacity. Hence, there will not be any gain or loss in capacity benefits at these projects as a result of changes in reservoir operation. The value of energy from these plants can be estimated by examining outside generation resources available to this system and how they will be used to meet loads during 1991 and subsequent years. Outside generation resources include Public Service Company of New Mexico's San Juan coal-fired steam plant; Basin Electric's Laramie River coal-fired steam plant in Wyoming; Department of Energy – Los Alamos Utilities gas-fired steam capacity; and Western Area Power Administration (Western) excess capacity.

At Elephant Butte, power generation is no longer marketed directly to individual utilities. It is marketed instead as a part of a system which also includes Reclamation's Colorado River projects. Since Western contracts power with Plains Electric and other users for delivery of a portion of the combined system output, the individual utilities would not be directly impacted by changes in the output of Elephant Butte. Western would be the entity feeling these impacts. They would have to purchase replacement power to make up any shortfalls or market for any excess. The value of any hydropower losses could vary, depending upon what type of operational change is proposed at Elephant Butte. The value of energy might change if operational adjustments require that the daily generating pattern be shifted to more of a base load or to more of a peaking operation than is presently followed.

Elephant Butte has value as a plant providing dependable capacity. This is a measure of its ability to carry peak load and is used to determine how much thermal generating capacity would be required in the power system if the hydro capacity were not available. The dependable capacity accounts for the periodic unavailability of part of the hydro plant's generating capacity due to the variability of hydrologic factors such as streamflow and reservoir elevation. For a hydro project in a thermal-based power system such as the Arizona-New Mexico system, dependable capacity would normally be computed as the average capacity available in the peak demand months. An alternative method would be to base dependable capacity on the capacity available for some specified percentage of the time during the peak demand months. The latter method is used by Western in estimating the marketable capacity of the hydro projects in their system. Elephant Butte contributes 27 megawatts of marketable capacity to the Western system, and marketable capacity will be used in this case as a measure of dependable capacity. Western bases marketable capacity on the capacity that is available 90 percent of the time during the peak demand months (which in this system are December and January in the winter and July and August in the summer). Some of the proposed reservoir operation plans could result in lower average pool elevations during these periods and hence a loss in dependable capacity. As an interim energy value for the 1991 study, subsequent to discussions with a Western representative and local utilities, market prices were used for the next 5 to 10 years (28.83 mills/kilowatt hours). After that period, Western customers would likely purchase replacement power from a new power plant (51.5 kilowatt hours) much of the time. An average of market price and the cost of new combined cycle plant is 40.2 mills/kilowatt hours.

The kilowatts estimated for each operating plan will be multiplied by the value of a hydropower kilowatt. The difference between plans will be measured on the basis of a $5^{5/8}$ percent interest level, current prices, and standard discounting procedures.

Thresholds for Significance

As discussed for other resources, a minimum change of 10 percent from No Action was considered to be the threshold of significance for identifying significant changes in performance between alternatives. This threshold considers the propagation of errors associated with input data, modeling, and spatial analyses.

Discussion of Results of Analysis

Hydroelectric power generation at Abiquiu and El Vado Reservoirs would continue as "run-of-the-river" power generation facilities generating power when releases are made. Under the No Action Alternative, there would be no change in hydropower generation. Elephant Butte Dam would continue to provide dependable power over the planning period, as projected by the Western Area Power Authority.

All action alternatives have the potential to increase hydroelectric power generation. **Table 4-26** provides a summary of the marginal output increases above the baseline power production projected for No Action.

Table 4-26. Marginal Increases in Hydropower by Alternative

Alter-native	Facility						Total Hydropower Benefit	Hydropower Rank
	Abiquiu		El Vado		Elephant Butte			
	Total Marginal Output		Total Marginal Output		Total Marginal Output			
	Megawatts	Dollars	Megawatts	Dollars	Megawatts	Dollars		
No Action	Baseline	$0	Baseline	$0	Baseline	$0	$0	7
B-3	15,260	$445,950	-640	($18,690)	34,750	$1,007,850	$1,435,110	6
D-3	67,600	$1,958,740	-490	($14,390)	34,900	$1,012,100	$2,956,450	3
E-3	68,820	$1,994,400	-380	($10,960)	34,700	$1,006,130	$2,989,570	2
I-1	63,310	$1,833,100	-160	($4,600)	11,440	$324,830	$2,153,330	5
I-2	67,270	$1,948,950	-230	($6,690)	27,490	$794,980	$2,737,240	4
I-3	68,880	$1,996,200	-270	($7,880)	34,920	$1,012,590	$3,000,910	1

Each action alternative would slightly decrease energy production at El Vado Reservoir as compared to the No Action Alternative, but the additional power output at Abiquiu and Elephant Butte Reservoirs would compensate for this loss at El Vado. On an annual basis, losses at El Vado Reservoir would be small, and there would be little impact to the reservoir hydroelectric output at El Vado from implementing any of the alternatives.

Sources of Uncertainty and Data Gaps

Changes since the 1991 study will have to be quantified and applied to the existing condition analysis as well as each alternative. Future development in this context includes both demand within the region and the resulting impact upon prices. Additionally, future development incorporating competing demands (e.g., Albuquerque's use of San Juan-Chama water) may impact the existing condition as well as each of the alternatives.

Summary/Comparison by Alternative

In general, each alternative would produce additional output at Abiquiu and Elephant Butte Reservoirs and would be differentiated by the amount of additional output produced at each reservoir. Each alternative would have the effect of lowering energy production at El Vado Reservoir, but the additional output at Abiquiu and Elephant Butte Reservoirs would more than make up for this loss. There would be a significant, positive impact even when considering the adverse effects of lower power output at El Vado

Reservoir. On an annual basis, El Vado's losses would be approximately $300 to $1,000, which falls within measurement tolerances.

Alternatives I-3, E-3, and D-3 result in the highest power revenues. Alternatives I-2, I-1, and B-3 provide the second tier in performance, with No Action providing the least hydropower production.

The bulk of excess hydropower generation revenue is realized at Abiquiu and Elephant Butte Reservoirs. Hydropower benefits from Abiquiu hydropower production is distributed directly to the City of Los Alamos. Elephant Butte is marketed as part of a system which also includes Reclamation's Colorado River projects. Since Western contracts the power with Plains Electric and other users for delivery of a portion of the combined system output, the individual utilities would not be directly impacted by changes in the output of Elephant Butte. Western would be in the position of marketing excess power produced.

Mitigation Measures

No mitigation measures are proposed for impacts to hydropower production associated with implementation of any of the proposed alternatives

4.4.8 Economics

4.4.8.1 Issues

Recreation has a significant impact on the regional economy – reservoir recreational spending alone may exceed $100 million annually. River recreation usage is not as well defined. Agriculture is also important to the area economy with market values for agricultural products exceeding $550 million annually. Agriculture, recreation, and tourism are aspects of the economy that are potentially related to proposed changes in water operations.

4.4.8.2 General Conclusions

Changes in water operations have the potential to impact regional and local economy by affecting agricultural lands, river and reservoir recreation, and tourism. Agriculture would be affected by proposed changes primarily in the Rio Chama below Abiquiu, with the greatest concerns associated with land inundation and overtopping of diversion structures. Water deliveries in the Central and San Acacia Sections had no significant differences between alternatives and the high degree of channelization and the levee system provide protections for agricultural land inundation. Agricultural economic impacts were not significant and were not evaluated in detail.

Increases in reservoir recreation above No Action were identified for all alternatives. Alternatives B-3, D-3, I-2, and E-3 all provided greater than $7 million increased reservoir recreation benefit. Alternatives I-1 and I-3 provided increases of $5.8 and $2.6 million, respectively. Alternatives B-3 and D-3 provided benefit at Heron, El Vado, Abiquiu, and Elephant Butte Reservoirs, whereas Alternative I-3 provided increased recreation at only Abiquiu and Elephant Butte.

4.4.8.3 Impact Indicators

Changes in visitation/tourism and economic benefit derived from reservoir recreation were used to evaluate potential impacts to local economies adjacent to water storage facilities.

Methods of Analysis

Visitation modeling results can be used to estimate the impacts of different alternatives on reservoir recreation activities. The common variable across alternatives is reservoir elevation. Holding all other variables constant at their current level, the URGWOM modeling results for reservoir elevation for each alternative can be input into the visitation model. This provides an estimate of the impact on visitation of changes in reservoir elevation associated with each alternative. All of the changes in visitation are compared to the No Action Alternative. Results are not presented for Jemez Canyon Reservoir because there was not enough variation in reservoir elevation to have any significant impact on visitation.

These visitation impacts can be translated into economic benefits if the benefit per visit is known. A net benefit value of $20 per visit was used to value the benefits of reservoir recreation. This value is based on the results for fishing and wildlife viewing activities for New Mexico published in *Net Economic Values for Wildlife-Related Recreation in 2001: Addendum to the 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* (FWS 2003c).

The 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation provides estimates of trip-related expenditures. Based on the survey results, trip-related expenditures are estimated to be $12 per trip.

Thresholds for Significance

The comparison performed evaluated marginal increases above baseline conditions provided by No Action. A 10 percent change was identified as potentially significant.

Discussion of Results of Analysis

Table 4-27 provides the results of the evaluation of reservoir recreation, as compared to No Action. All alternatives increased recreational opportunities at the four reservoirs evaluated. Alternatives B-3 and D-3 increased visitation at Heron, El Vado, Abiquiu, and Elephant Butte Reservoirs. Alternatives E-3, I-1, and I-2 provided increased recreation at El Vado, Abiquiu, and Elephant Butte Reservoirs. Alternative I-3 increased recreation only at Abiquiu and Elephant Butte Reservoirs.

Table 4-27. Marginal Increase in Reservoir Recreation above No Action

Altern-ative	Facility								Total Added Economic Benefit	Reservoir Recreation Rank
	Heron Reservoir		El Vado Reservoir		Abiquiu Reservoir		Elephant Butte Reservoir			
	Increase in Annual Recreation		Increase in Annual Recreation		Increase in Annual Recreation		Increase in Annual Recreation			
	Visitors	Dollars	Visitors	Dollars	Visitors	Dollars	Visitors	Dollars		
No Action	Baseline	$0	Baseline	$0	Baseline	$0	Baseline	$0	$0	7
B-3	10,250	$205,000	500	$10,000	53,000	$1,060,000	329,000	$6,580,000	$7,855,000	1
D-3	6,100	$122,000	500	$10,000	42,500	$850,000	333,300	$6,666,000	$7,648,000	2
E-3	0	$0	500	$10,000	45,050	$901,000	329,650	$6,593,000	$7,504,000	4
I-1	0	$0	150	$3,000	31,600	$632,000	257,900	$5,158,000	$5,793,000	5
I-2	0	$0	350	$7,000	45,400	$908,000	332,150	$6,643,000	$7,558,000	3
I-3	0	$0	0	$0	12,050	$241,000	117,450	$2,349,000	$2,590,000	6

4.4.8.4 Summary/Comparison by Alternative

The largest increase in visitation would occur at Elephant Butte Reservoir, with a potential beneficial impact of approximately 19 percent. All of the alternatives would have a positive impact or no impact on visitation compared to the No Action Alternative, assuming zero diversions to the LFCC under No Action.

4.4.8.5 Mitigation Measures

No mitigation measures are proposed for economic impacts, as all action alternatives offer potential improvements to recreation and tourism as compared to the No Action Alternative.

4.4.9 Environmental Justice

4.4.9.1 Issues

Environmental justice addresses the potential for disproportionate impacts on minority and/or low-income populations. According to the distribution of racial/ethnic populations in the planning area and a comparison of income and poverty rates to state averages, most counties in the planning area qualify for consideration of disproportionate impacts. In New Mexico, counties not considered for disproportionate impact analysis include: Bernalillo, Los Alamos, and Santa Fe counties comprising the northern portion of the Central Section. As water operations changes did not affect the Northern or Southern Sections, no detailed analysis was performed.

4.4.9.2 General Conclusions

Environmental justice concerns were evaluated by considering resources with potential adverse impacts. Riverine, reservoir, riparian, threatened and endangered species, and cultural resources were considered in the evaluation. The Rio Chama and San Acacia Sections had greater minority populations than the Central Section. Across all alternatives, the Central Section received the greatest potential benefit, while both the Rio Chama and San Acacia Sections incurred the greatest potential adverse impacts.

Alternatives B-3 and I-2 offered greater benefits than No Action for environmental justice concerns. However, Alternatives B-3 and I-3 provided beneficial improvements in resource conditions in two of three river sections evaluated. Alternative B-3 improved resource conditions in the Rio Chama and Central Sections. Alternative I-3 improved resource conditions in the Central and San Acacia Sections, but was ranked sixth due to the magnitude of adverse impacts observed. Other alternatives were typically beneficial or neutral in impacts on resources within the Central Section, with adverse impacts observed in both the Rio Chama and San Acacia Sections. Alternatives I-1 and I-3 offered the least difference in impact across all three river sections. No Action was considered neutral and was ranked third among the alternatives.

4.4.9.3 Impact Indicators

Resources with significant adverse impacts were selected for evaluation on the distribution of those impacts by river section. Impacts were considered for riverine, reservoir, riparian, threatened and endangered species, and cultural resources. All of the analyses for these resources identified impacts potentially requiring mitigation.

Methods of Analysis

Impacts of alternatives for each river section were compared to the No Action Alternative for each resource. Thus, the No Action Alternative is neutral with respect to environmental justice concerns. No changes were anticipated for the Northern and Southern Sections. Only the Rio Chama, Central, and San Acacia Sections were evaluated for environmental justice considerations. Within these sections all the resources experienced significant adverse impacts when compared to the No Action Alternative.

Thresholds for Significance

Adverse impacts greater than 10 percent different from conditions expected under No Action for each resource were considered in this analysis. This threshold was selected to exclude sources of error associated with input data as well as potential propagation of error across the use of multiple models and analytical methods. However, for threatened and endangered species, the tolerance for significance when compared to No Action was raised to 5 percent due to the critical status of these species.

Discussion of Results of Analysis

The environmental justice evaluation is summarized in **Table 4-28**. No Action, as the baseline condition, was assumed neutral for all river sections. Alternatives were compared to No Action and identified as offering beneficial or adverse impacts for each resource evaluated. Rankings were based on numerical conversion of verbal ratings to scores: neutral = 0, beneficial = +1, slight loss = -0.5, and adverse = -1.

Table 4-28. Summary of Environmental Justice Evaluation

Section	Alternatives						
	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Aquatic-Riverine Environment							
Rio Chama	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Central	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
San Acacia	Neutral	Adverse	Adverse	Adverse	Neutral	Neutral	Adverse
Aquatic-Reservoir Environment							
Rio Chama	Neutral	Beneficial	Mixed	Mixed	Adverse	Adverse	Adverse
Central	Neutral	Beneficial	Beneficial	Beneficial	Neutral	Beneficial	Beneficial
San Acacia	NA	NA	NA	NA	NA	NA	NA
Riparian Resources							
Rio Chama	Neutral	Beneficial	Adverse	Adverse	Adverse	Adverse	Adverse
Central	Neutral	Beneficial	Neutral	Neutral	Neutral	Neutral	Adverse
San Acacia	Neutral	Neutral	Slight Loss	Neutral	Neutral	Beneficial	Beneficial
Threatened & Endangered Species							
Rio Chama	NA	NA	NA	NA	NA	NA	NA
Central	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
San Acacia	Neutral	Slight Loss	Slight Loss	Slight Loss	Neutral	Beneficial	Slight Loss
Cultural Resources							
Rio Chama	Neutral	Beneficial	Adverse	Neutral	Neutral	Neutral	Neutral
Central	Neutral	Adverse	Neutral	Adverse	Neutral	Neutral	Neutral
San Acacia	Neutral	Adverse	Adverse	Adverse	Adverse	Adverse	Adverse
Rank	**3**	**1**	**7**	**5**	**4**	**2**	**6**

NA = Not analyzed.

Sources of Uncertainty and Data Gaps

Environmental justice considerations are derived from the cumulative uncertainties and data gaps underlying the other individual resource analyses. Population distributions and incomes may change with time, thereby changing the socioeconomic profile of the planning area.

There would be potential environmental justice concerns related to aquatic river resources associated with all alternatives due to impacts in areas with a low income, high unemployment, relatively high Hispanic population, and/or a relatively high Native American population. More limited impacts were identified for reservoir resources, riparian habitat, and threatened and endangered species. However, these impacts are more widespread due to the nature of the resource and may not represent a significant environmental justice concern.

Alternative I-1 has the least potential for environmental justice concerns, followed equally by Alternatives I-2, I-3, and D-3. Alternatives B-3 and E-3 would both result in adverse cultural resources impacts in sensitive areas.

4.4.9.4 Mitigation Measures

No mitigation measures are proposed regarding environmental justice considerations apart from the resource-specific mitigations recommended.

4.4.9.5 Summary/Comparison by Alternative

Impacts of alternatives for each river section were compared to the No Action Alternative for each resource; results indicated that either positive or no change would be expected for the Northern and Southern Sections. River sections evaluated further for environmental justice considerations included the Rio Chama, Central, and San Acacia Sections. Within these sections, five resource areas would experience significant adverse impacts compared to No Action Alternative, including aquatic-riverine resources, aquatic-reservoir resources, threatened and endangered species, riparian resources, and cultural resources. The following discussion of the ranking of alternatives provides a comparison of the impacts of the alternatives.

4.5 Selecting the Preferred Alternative

4.5.1 Method

By applying the rankings derived from the criteria in the decision-support software, a preferred alternative was identified. This alternative is not the same as the environmentally preferable alternative, but was selected because it met the most criteria. No alternative was determined to be ideal for all resources, but this method of considering how well the alternatives met the threshold criteria in addition to those criteria determined to be important by the JLA and Steering Committee provided a tool to rank the alternatives for the decision makers.

Alternatives were evaluated using the performance measures and scored for maximum benefit. Where quantitative analysis was possible, if an alternative provided the maximum beneficial result, it received a score of 100 percent. Alternatives with lesser results received a score reflecting the percentage of the maximum resource benefit attainable. Where quantitative information was not available, qualitative scoring was performed using simple scales ranging from 1 to 10 and descriptors such as good, fair or poor. This information was input into the decision support software and the results are presented below.

4.5.2 Discussion

More detailed decision hierarchy reflecting sub-criteria and performance measures is shown on **Figure 4-33**. Appendix P provides additional details on the performance measures and development of alternative scores. Attachments to the appendix contain performance measure evaluations conducted by each resource teams

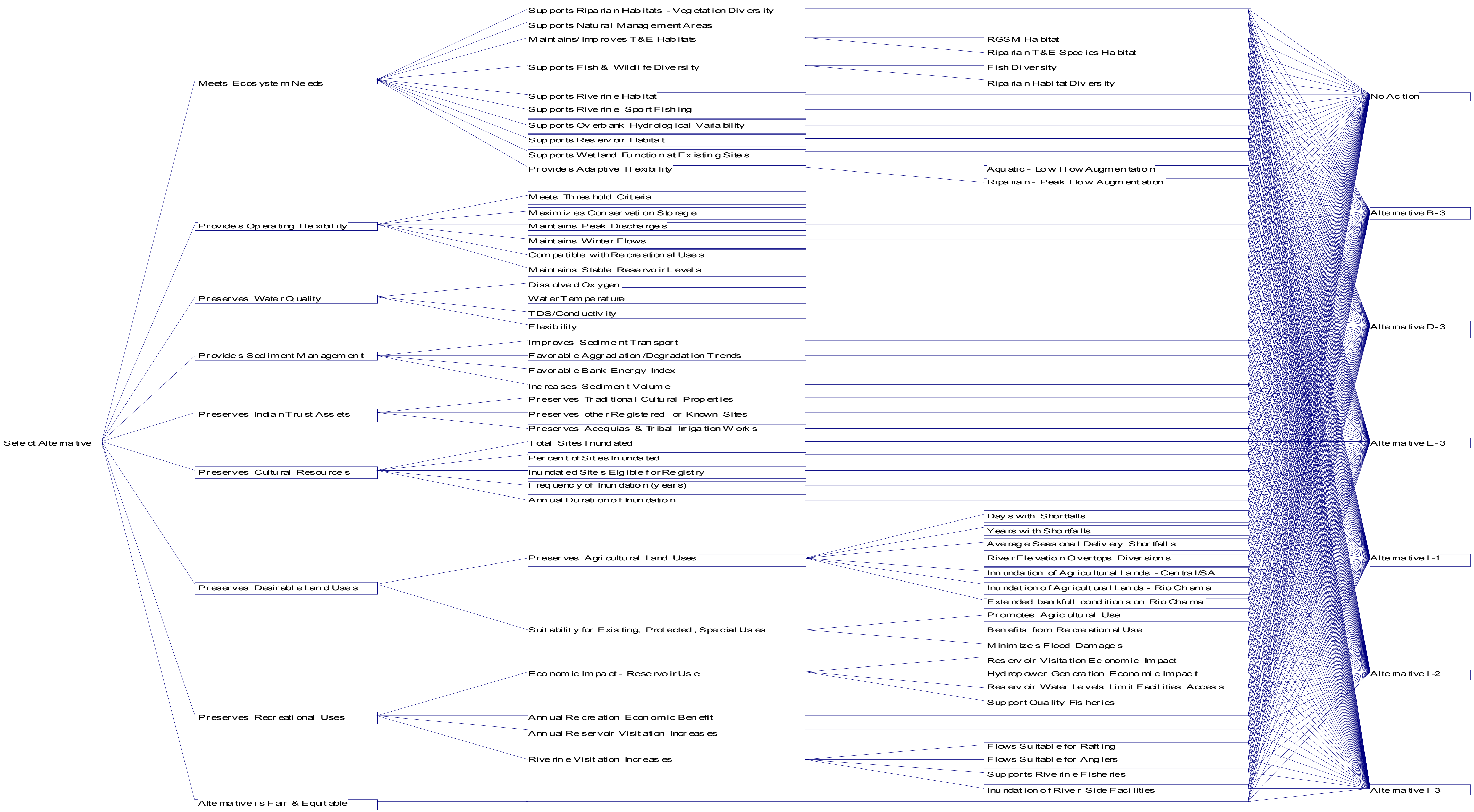


Figure 4-33. Detailed Decision Hierarchy

Table 4-29. Decision Performance Scores for Alternative Selection

Weights	Criteria	Weights	Performance Measure	Weights	SubCriteria	ALTERNATIVE SCORE						
						No Action	B-3	D-3	E-3	I-1	I-2	I-3
20	Meets Ecosystem Needs	14	Supports Riparian Habitats - Vegetation Diversity			63.6	44	65.4	57.8	89.3	76.9	58.3
		4	Supports Natural Management Areas			93.4	57.7	53.8	59.2	88.1	79.9	60
		8	Maintains/Improves T&E Habitats	43.5	RGSM Habitat	94.71	95.77	95.92	95.95	99.52	99.5	95.78
				56.5	Riparian T&E Species Habitat	70.1	59	53.6	66.4	77.7	70.1	53.5
		10	Supports Fish & Wildlife Diversity	78.5	Fish Diversity	82.76	69.59	74.85	72.94	75.52	86.91	91.12
				21.5	Riparian Habitat Diversity	76.7	57.4	70	62.2	87.1	75.2	63.5
		22	Supports Riverine Habitat			99.52	92.05	91.15	91.78	93.79	93.75	90.58
		2	Supports Riverine Sport Fishing			99.32	98.25	98.76	98.48	100	99.43	98.39
		16	Supports Overbank Hydrological Variability			55.4	78.2	76	88.6	76.1	74.6	74.1
		10	Supports Reservoir Habitat			92.91	83.55	80.52	80.81	77.12	66.69	64.83
		8	Supports Wetland Function at Existing Sites			99.1	95	94.6	95	97.4	96.4	95
		6	Provides Adaptive Flexibility	50	Aquatic - Low Flow Augmentation	48.1	100	94.2	94.7	55.8	77.4	95.7
				50	Riparian - High Flow Augmentation	16	96	89	97	30	66	91
17.78	Provides Operating Flexibility	37.5	Meets Threshold Criteria			50	83	89	94	58	72	95
		25	Maximizes Conservation Storage			0	98	95	95	50	76	96
		20	Maintains Peak Discharges			83	90	87	88	85	100	88
		10	Maintains Winter Flows			94	100	96	97	96	96	97
		5	Compatible with Recreational Uses			100	92	92	90	95	92	90
		2.5	Maintains Stable Reservoir Levels			90	98	96	97	88	93	98
15.56	Preserves Water Quality	34.57	Dissolved Oxygen			99.75	90.75	92	93.25	93.25	94	93.25
		41.47	Water Temperature			73	99.5	97	96.75	96.75	93.25	97
		23.04	TDS/Conductivity			88.25	100	98.5	98.5	98.5	98.5	98.5
		0.92	Flexibility			0	100	14.37	19.38	1.17	2.47	21.11
13.33	Provides Sediment Management	25	Improves Sediment Transport			100	76	77	76	87	82	77
		25	Favorable Aggradation/Degradation Trends			93	96	91	94	75	83	93
		25	Favorable Bank Energy Index			99	90	90	89	95	92	89
		25	Increases Sediment Volume			100	79	80	80	89	84	80
11.11	Preserves Indian Trust Assets	40	Preserves Traditional Cultural Properties			50	75	50	75	66.67	66.67	66.67
		30	Preserves other Registered or Known Sites			50	75	50	50	66.67	66.67	66.67
		30	Preserves Acequias & Tribal Irrigation Works			50	75	50	50	66.67	66.67	66.67
8.89	Preserves Cultural Resources	25	Total Sites Inundated			92	88	100	82	94	94	99
		20	Percent of Sites Inundated			86	83	97	73	92	92	100
		10	Inundated Sites Eligible for Registry			80	100	24	24	83	83	83
		20	Frequency of Inundation (years)			46	100	100	100	46	55	86
		25	Annual Duration of Inundation			29	100	100	100	29	50	50
6.67	Preserves Desirable Land Uses	50	Preserves Agricultural Land Uses	10	Days with Shortfalls	82.05	81.95	80.03	80.15	81.9	80.13	81.75
				10	Years with Shortfalls	49.38	50.63	49.08	50.63	50.63	49.08	49.08
				30	Average Seasonal Delivery Shortfalls	82.05	82	81.78	81.85	81.9	81.8	81.75
				10	River Elevation Overtops Diversions	57.9	66.5	61.7	59.6	56.7	58.8	59.6
				10	Inundation of Agricultural Lands - Central/SA	96.6	97.05	95.88	96.83	95.65	96.2	96.78
				10	Inundation of Agricultural Lands - Rio Chama	90.23	89.9	83.97	86.27	80.37	83.63	85.9
				20	Extended bankfull conditions on Rio Chama	78	100	86.7	87.3	78.7	87.3	78
		50	Suitability for Existing, Protected, Special Uses	40	Promotes Agricultural Use	7.7	8.3	6.6	7.9	7.6	7.7	7.9
				30	Benefits from Recreational Use	5.3	5.6	5.9	6	5	5.5	6
				30	Minimizes Flood Damages	4	15	100	11	6	12	86
4.44	Preserves Recreational Uses	40	Economic Impact - Reservoir Use	25	Reservoir Visitation Economic Impact	56	100	99	98	88	98	71
				25	Hydropower Generation Economic Impact	77	87	100	100	93	98	100
				45	Reservoir Water Levels Limit Facilities Access	51.98	54.48	59.7	60	46.73	53.78	60.05
				5	Support Quality Fisheries	59.7	52.8	51.2	50.9	100	94.3	92.2
		20	Annual Recreation Economic Benefit			56	100	99	98	88	98	71
		20	Annual Reservoir Visitation Increases			56	100	99	98	88	98	71
		20	Riverine Visitation Increases	53	Flows Suitable for Rafting	52	51	51	53	52	52	53
				32	Flows Suitable for Anglers	53.67	60.33	61.33	60.33	54.67	57.67	60.33
				11	Supports Riverine Fisheries	99.32	98.25	98.76	98.48	100	99.43	98.39
				4	Inundation of River-Side Facilities	100	100	98.33	100	95.67	99.17	100
2.22	Alternative is Fair & Equitable					3	1	7	5	4	2	6

4.5.3 Results

The performance and relative ranking of alternatives in accordance with resource team criteria and performance measures are documented in **Table 4-29**, in the CDP model file, and in the team spreadsheets as discussed in Appendix P. The decision hierarchy, performance measures, weights and alternative scores are all summarized in the table. The scores reflected in Table 4-29 are normalized so that maximum resource benefits have a score of either 100 or 10, depending on the evaluation scale used. Alternatively, where qualitative analyses were performed, a simple ranking from one to seven was used – for example, in evaluating alternative fairness and equity. The final selection of a preferred alternative is based on the most favorable weighted score among all performance measures across all resources in accordance with the weights developed by the JLA, Steering Committee, and stakeholders. Alternative rank by performance on the major selection criteria is shown on **Figure 4-34**.

Alternative B-3 is the preferred alternative. A more detailed comparison of alternative performance by criterion is shown on the radar diagram in **Figure 4-35,** with alternatives listed in order of preference in the legend. The best-performing alternative occupies the greatest area on the diagram. Better performance on a single criterion is indicated by line position at a greater distance from the centerpoint. A wide distribution across a single axis indicates a greater degree of difference in alternative performance. The largest variability in alternative performance occurs under operating flexibility, cultural resources, Indian trust assets, and land use support. Lesser variability between alternatives was observed for ecosystem needs, water quality, sediment management, and recreational uses.

Alternative performance relative to the threshold criteria is shown on **Figure 4-36**. Alternatives I-2, I-1, and No Action do not satisfy minimum requirements for compact deliveries and also offer lesser degrees of flood control.

Alternative performance for operating flexibility is shown on **Figures 4-37**. Alternative I-3 is the preferred alternative from a water operations flexibility perspective. Alternatives I-2, I-1, and No Action did not meet minimum threshold criteria for selection based on their inability to satisfy interstate compact deliveries. The preferred alternative, B-3, ranked fourth in operating flexibility. Alternative B-3 provides the greatest opportunity to maximize native conservation storage in Abiquiu Reservoir, to hold storage in Heron Reservoir with a September 30 waiver date. This alternative had decreased channel capacity below Abiquiu Dam and increased channel capacity below Cochiti Dam. LFCC operations ranged from 0 to 2,000 cfs under Alternative B-3.

As shown on **Figure 4-38**, Alternatives I-1, I-2, and E-3 are the top three environmentally-preferred alternatives based on support for aquatic and riparian resources, including consideration for threatened and endangered species. The preferred alternative, B-3, ranked last in ecosystem support, providing support for reservoir aquatic habitats, but lesser support for riverine and riparian habitat diversity.

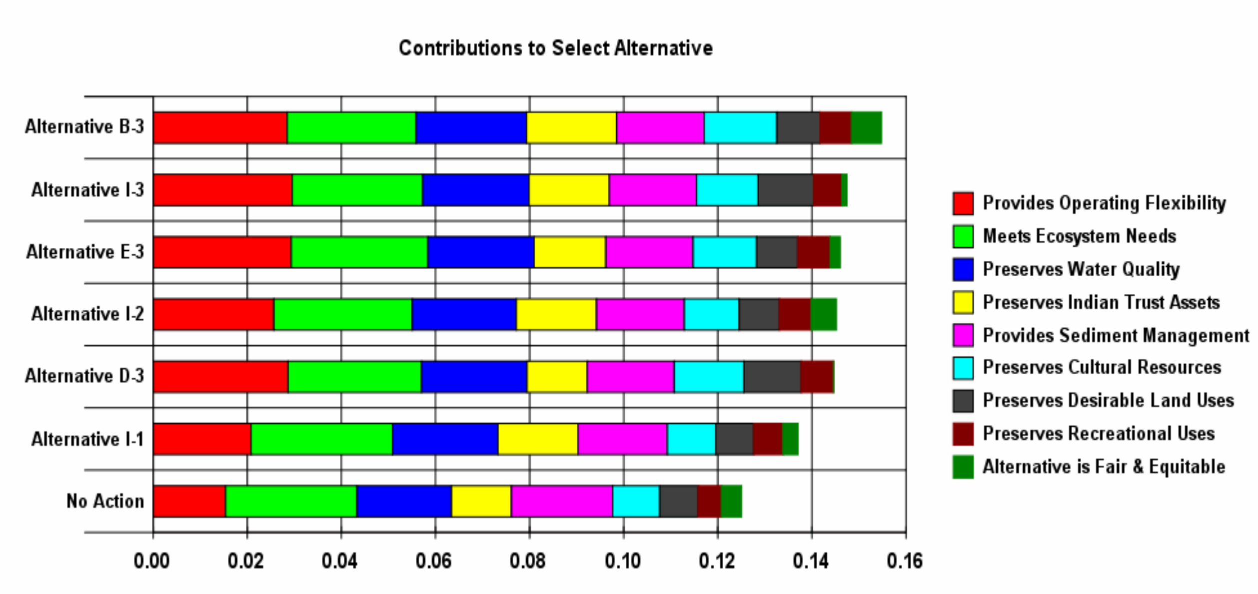


Figure 4-34. Final Ranking of Alternatives

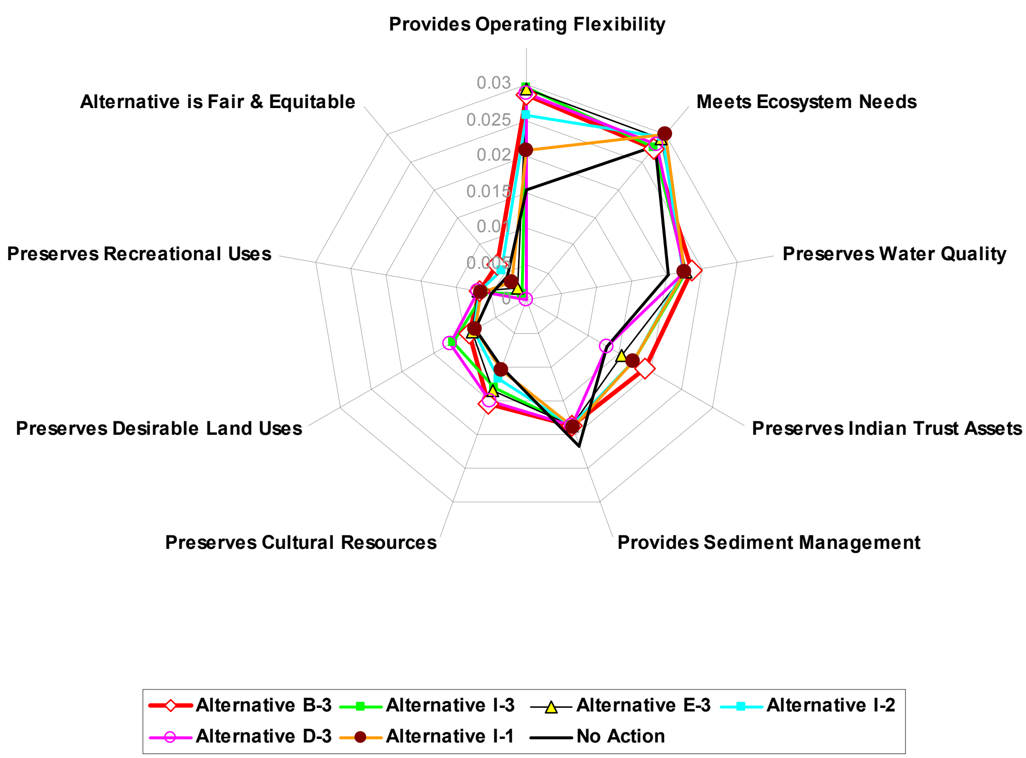


Figure 4-35. Radar Diagram of Alternatives

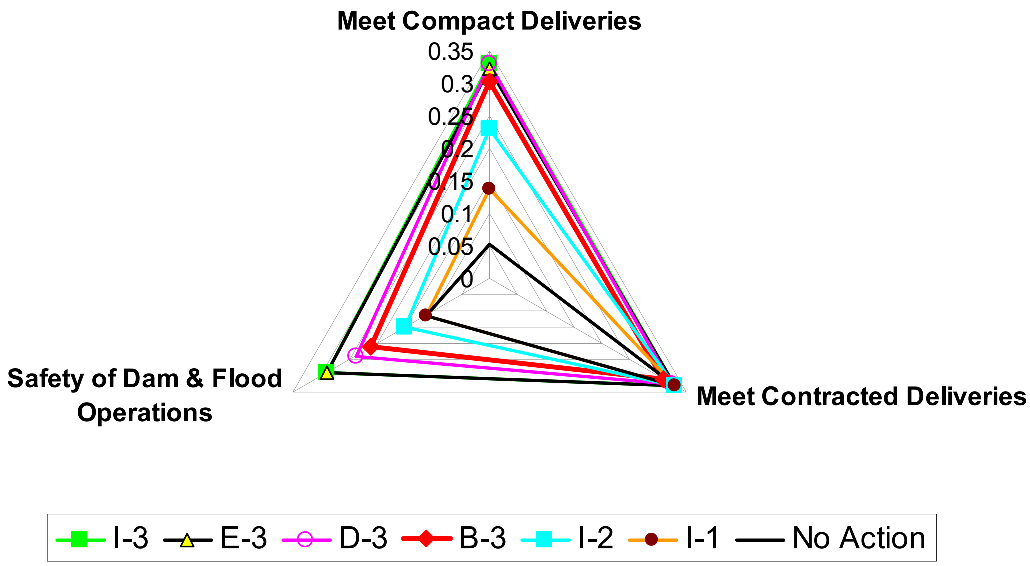


Figure 4-36. Threshold Criteria

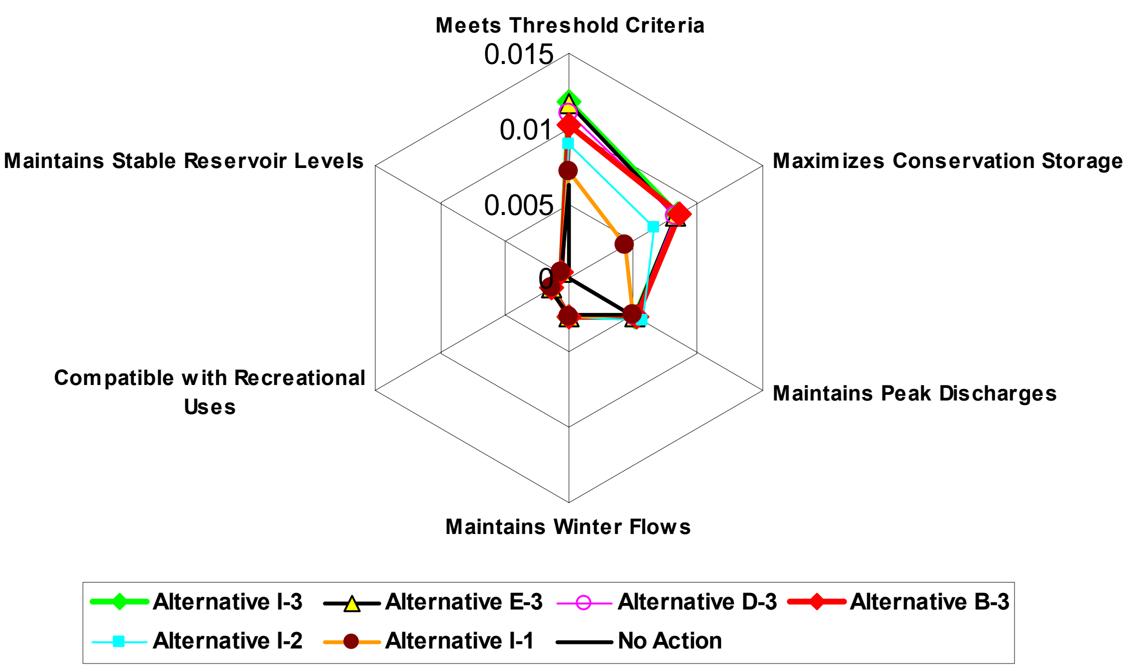


Figure 4-37. Operating Flexibility

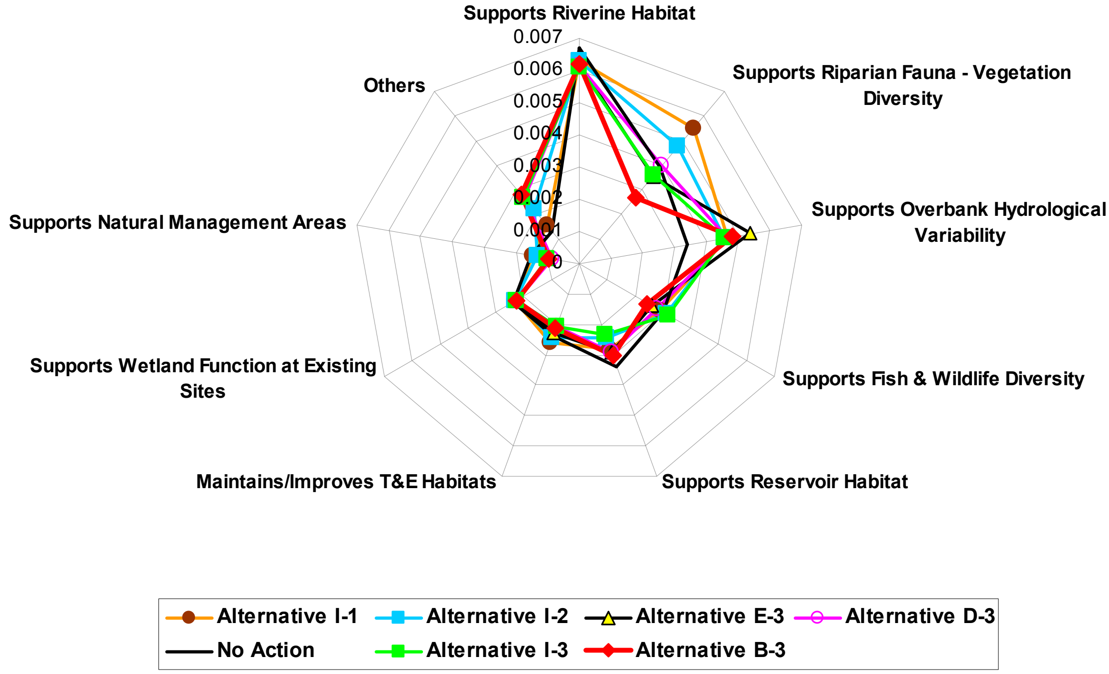


Figure 4-38. Ecosystem Support

4.6 Cumulative Impacts

Council of Environmental Quality regulations implementing NEPA define cumulative impacts as "the impact on the environment which results from the incremental impact of action when added to other past, present, and reasonably foreseeable future actions regardless of which agency (Federal or non-Federal) or person undertakes such actions" (40 CFR section 1508.7). As this EIS considers a 40-year planning period, there are numerous past, present, and reasonably foreseeable actions in the planning area. This analysis focused on actions that may have a continuing, additive, or significant relationship to the impacts of the proposed alternative. This process was conducted by public scoping, consultation with cooperating agencies, tribal governments, and other stakeholders in the planning area, and through conversations among JLA representatives.

The identified actions for cumulative effects assessments were considered for actions implemented within the next 5 years, with operational impacts assessed for the 40-year planning period. The geographical scope of the analysis included the planning area extending from the Closed Basin Project in Colorado to Fort Quitman, Texas. Unless noted, cumulative impacts would be similar for all alternatives. The table is organized by resource, as presented in Chapters 3 and 4.

Table 4-30 summarizes the cumulative impacts expected under the preferred alternative.

1 **Table 4-30. Summary of Cumulative Impacts**

Project	Description	Time Period	Resource Impact
Bureau of Reclamation - Rio Grand and LFCC Modifications	This project proposes to realign the river channel and LFCC between San Acacia Diversion Dam and Elephant Butte Reservoir to improve water conveyance, enhance valley drainage, and improve sediment management.	Planning stages only; duration indefinite.	This EIS considers possible operating impacts for a reconfigured LFCC ranging from 500 to 2,000 cfs. However, changes due to physical realignment are not addressed. This project has the potential to affect flows in the San Acacia Section.
Bureau of Reclamation - Middle Rio Grande River Maintenance and Flood Protection	Reclamation maintains the river channel for the Middle Rio Grande Project from Velarde to Caballo Dam with the goals of effective water conveyance; water conservation; reducing aggradation; and protecting riverside structures and facilities.	Ongoing; duration indefinite	River maintenance activities complement the actions considered under water operations alternatives including bank stabilization, bioengineering, and habitat enhancements, river training works, sediment removal, vegetation control, levee maintenance.
U.S. Army Corps of Engineers- Belen Levee Project	This project extends from Isleta Pueblo to Belen, NM along both banks of the Rio Grande. The existing spoil-bank levee would be rehabilitated to withstand higher and longer duration floods, accommodating the safe release of higher flows from upstream flood control reservoirs.	Planning stages; duration indefinite.	Completion of this project is critical to the implementation of any alternative that calls for a channel capacity greater than 7,000 cfs in the Central Section.
U.S. Army Corps of Engineers, Rio Grande Floodway Rehabilitation	This project affects the east bank of the Rio Grande from the san Acacia Diversion Dam downstream to the San Marcial Railroad bridge. This project will rehabilitate the existing spoil-bank levee and relocate and increase the channel capacity below the railroad bridge.	Planning stages; duration indefinite.	This EIS assumes that the San Marcial railroad bridges restriction on channel capacity is removed resulting in the ability to pass higher peak flows from upstream reservoirs. Completion of this project is critical to the implementation of any alternative that calls for a channel capacity greater than 7,000 cfs in the Central Section.
U.S. Army Corps of Engineers, Abiquiu Dam Oxygenator Project	This project considers modifications to the hydroelectric plant that would improve water quality below Abiquiu Dam in conjunction with power generation conducted by Los Alamos County.	Planning stages; duration indefinite.	Dissolved oxygen concentrations were a concern in the Southern Section - Elephant Butte and Caballo Reservoirs. Upstream improvements may also help downstream dissolved oxygen concentrations. This project will directly affect the Rio Chama Section, with lesser impacts downstream.

Project	Description	Time Period	Resource Impact
U.S. Army Corps of Engineers, Jemez Canyon Dam and Reservoir EA	This project considers long-term operation of Jemez Canyon Dam and Reservoir as a dry reservoir.	Court order; duration indefinite	This EIS treats Jemez Canyon Reservoir as a dry reservoir.
Middle Rio Grande Endangered Species Collaborative Program	This multi-agency and public collaborative program authorizes the planning, evaluation, and funding of projects to improve habitat, conduct research, and obtain water to benefit federally listed species.	Ongoing; duration indefinite	Adaptive management activities anticipated as a result of implementing the preferred alternative should be coordinated through the Collaborative Program to ensure that water operations changes are contributing to recovery efforts for the species.

4.7 Short- and Long-Term Impacts

Section 102(2)(c)(iv) of NEPA and 40 Code of Federal Regulations (CFR) 11502.16 require comparison of the relationships between short-term uses of the human environment to the maintenance and enhancement of long-term productivity. None of the alternatives propose construction activity, thus there would be no construction-related short-term impacts. Action alternatives would result in operational changes in storage and release patterns from reservoirs and possibly contribute to land use changes in the basin. Long-term impacts would assist in conserving the RGSM, the SWFL, and better managing the limited water supply for the benefit of multiple users. Irreversible and irretrievable commitments are discussed in Section 4.8.1.

4.8 Unavoidable Adverse Impacts

Unavoidable adverse impacts are assumed to be long-term impacts to resources caused by implementation of an action alternative. Resources which can demonstrate notable adverse impacts include aquatic, riparian, water quality, and cultural resources. Specific mitigation measures are proposed for each of these resources to reduce the magnitude of impacts. With the exception of overbank flooding and attendant biological impacts in the San Acacia Section, impacts can be offset or mitigated to levels that would be better than under the No Action Alternative for each water operations alternative. However, seasonal restrictions on diversions to the LFCC could further improve the biological impacts in the San Acacia Section under all alternatives. However, restrictions would be deferred until specific actions are proposed by Reclamation, as physical limitations currently preclude active diversion to the LFCC. Primary impacts to water quality are related to dissolved oxygen in Elephant Butte and Caballo Reservoirs – direct and indirect measures can be used to increase flows and/or oxygenate waters. Impacts to cultural resources are associated with excessive flood flows in the San Acacia Section. Higher flood flows are desired to promote biological resources, but are also associated with potentially irreversible and irretrievable damages to known and unknown cultural resources sites. Thus, flood barriers such as coffer dams would be needed to reduce the impacts of higher flows. Diversions to the LFCC can also decrease the potential for damages associated with mainstem river flooding.

4.9 Irreversible or Irretrievable Commitments

Section 101 (2) (c)(v) of NEPA and 40 CFR 1502.16 require a discussion of irreversible and irretrievable commitment of resources. "Irreversible commitment of resources" is interpreted to mean those resources, once committed to the proposed alternative, would continue to be committed throughout the duration of operations; and that those resources used, consumed, destroyed, or degraded during operations under the proposed alternative could not be retrieved or replaced for the life of the operations or beyond.

Archaeological sites and Traditional Cultural Properties are the only resources potentially irreversibly and irretrievably affected by implementation of any of the alternatives, even with some of the proposed mitigation measures. For example, if the most appropriate mitigation measure were to excavate an archaeological site, this would permanently remove the site from its context.

Environmental commitments implemented for the selected alternative are intended to avoid, mitigate, or compensate for adverse impacts that would otherwise occur as a result of implementing the selected water operations alternative. In some cases, these commitments help ensure that activities are conducted in accordance with applicable laws and guidelines.

4.9.1 Environmental Commitments

Environmental commitments are actions that may be implemented upon the selection of any of the alternatives. These commitments are intended to avoid, mitigate, or compensate for adverse environmental impacts that would otherwise occur. Resources that may require additional environmental commitments are listed below.

- Threatened and Endangered Species Management
- Riparian Habitat
- Water Quality
- Cultural Resources

An adaptive management program will be implemented common to all alternatives. An adaptive management program will provide guidance for monitoring EIS targets, compliance with current Biological Opinions, addressing changing conditions in the future management of water operations within established parameters, and providing a framework for ensuring that the selected alternative satisfies the purpose of and need for the proposed action. The proposed adaptive management program is discussed in more detail in the following section.

4.10 Adaptive Management

4.10.1 Summary

Resource impacts were evaluated based on the quality of data available and current understanding of the system. However, as actions are implemented, further data are gathered, improvements in modeling and predicting system behavior occur, and agencies and stakeholders continue to cooperate and balance the ever-changing needs of natural ecosystems, a process for active and adaptive management is needed.

The question becomes, "*How do we adjust and integrate our program of operations in a manner that best serves the multiple and competing uses along this river system*?"

Adopting an adaptive management program is one approach that allows for science-based research and monitoring of responses to previous decisions. Monitoring information is analyzed and used to guide future decisions concerning human activities. Overarching management and ecosystem objectives remain fixed over time, and actions are adjusted to assure that future actions taken or modified promote sustainable positive impacts, to the degree possible and foreseeable. A general schematic of the adaptive management program is shown in **Figure 4-39.**

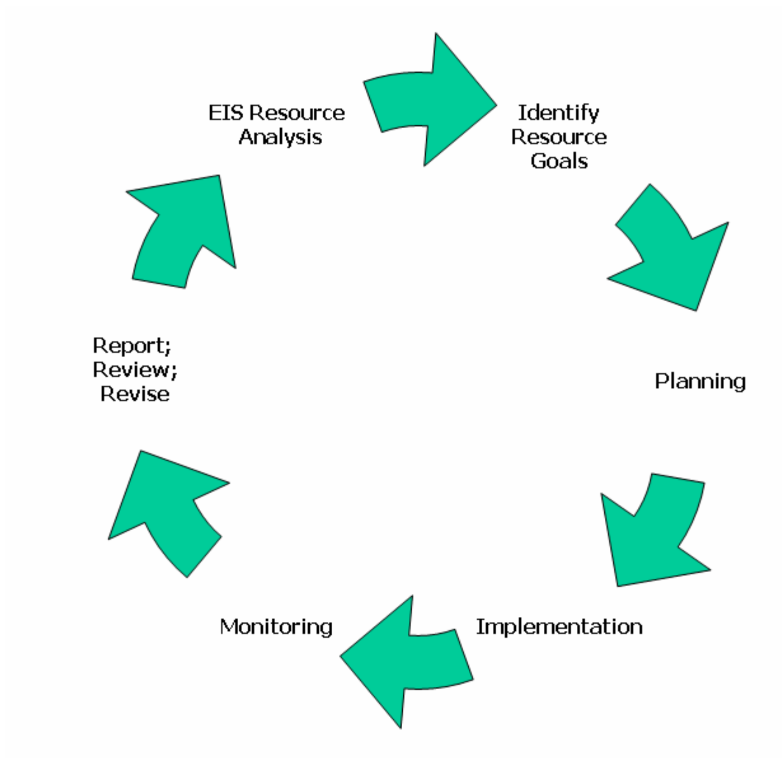


Figure 4-39. Overview of Adaptive Management Process

4.10.2 Goals and Objectives

In the upper Rio Grande basin, an adaptive management program would promote managing Federal facilities within an overall scientific-economic policy framework where decisions are based on data resulting from scientific inquiry and measured impacts. This decision framework can be considered as "continuing NEPA in action." Under adaptive management, proposed actions are implemented, a period of monitoring and research occurs, and modified actions are implemented based on analysis of data collected, with cycles of further measurement and adjustment continuing to reach and sustain management objectives. Water managers and stakeholders must first agree on acceptable or desirable conditions (management objectives) specific to the Rio Grande and then commit to developing and practicing the art of adjusting operations to sustain those conditions.

4.10.3 Process

Adaptive management activities in the Rio Grande system are underway. Multi-stakeholder collaborative efforts are ongoing in various portions of the basin, including the Middle Rio Grande ESA Collaborative Program and the Paso del Norte Watershed Council, and various regional water planning and watershed management groups.

Despite the actions of these agency and stakeholder groups, an overarching need exists for cooperative, adaptive management implementation across the entire study area encompassing the Federal facilities considered in this Review and EIS. A formal adaptive management program could be developed that extends from the Closed Basin Project and headwaters of the Rio Grande in Colorado to Fort Quitman, Texas with the charge of monitoring results of implementing the preferred alternative adopted by the JLAs and documented in individual agency Records of Decision. The adaptive management program could be administered through a formal, chartered organization representing the JLA, cooperating agencies, and stakeholders, that could transition into an advisory committee. The purpose of the adaptive management organization includes:

- Defining and recommending resource management objectives
- Conducting any additional research or studies to determine the impacts on various resources of the effects of operations conducted at Federal facilities along the Rio Grande
- Facilitating input and coordination of information among stakeholders
- Monitoring and reporting on regulatory compliance

4.10.4 Future Adaptive Management Activities

This EIS is a planning document and does not authorize specific projects. Rather, it provides a range of preferred water operations in the Upper Rio Grande Basin under the agencies' existing authorities. Any specific federal action proposed in the future would require its own NEPA process and environmental document. Detailed adaptive management plans would be developed as specific federal actions are proposed and implemented.

The baseline data, models, and analyses contained in this EIS would assist in the design and implementation of detailed adaptive management plans for future specific agency actions. Adaptive management and monitoring plans would need to be coordinated with other adaptive management activities being undertaken in the basin, such as those associated with the Middle Rio Grande ESA Collaborative Program and the City of Albuquerque San Juan-Chama Drinking Water Project.

The data quality database created as part of this EIS (Appendix P) identifies areas where data quality was insufficient or lacking. Adaptive management plans that are formulated should focus on areas where data gaps have been identified in order to validate, or correct, assumptions and conclusions that were made on the basis of insufficient data.

Sources of uncertainty and data gaps are summarized in the EIS for each resource area, and include:

- URGWOM Planning Model
    - Accuracy of flow predictions due to effects of groundwater/surface water interactions.
    - Effects of evapo-transpiration on flow predictions.
    - Improve predictions of how water moves through the system, i.e., improve determination of delivery schedules for differing water uses (e.g., recreation, irrigation).
- Aquatic Habitat
    - Predicted changes to riverine and reservoir aquatic habitat are subject to propagation of gage and URGWOM modeling error, understanding of desirable fish habitat conditions, model spatial sensitivity, and further propagation of error across the Aquatic Habitat and FLO-2D models.
- Riparian Habitat
    - Quality and limitations of each data set for the riparian analysis depend on modeled data and uncertainties in input data, including gage error and hydrologic inputs.
- Threatened and Endangered Species
    - Model predictions in the San Acacia Section offer less certainty than those offered for other sections due to limitations in modeling highly dynamic and unstable river and riparian environments. Conclusions regarding habitat and life-stage requirements for many of the species are based on current understanding and will continue to evolve.
- Water Quality
    - Flow-based differences in various water quality parameters need to be more thoroughly evaluated.

- Indian Trust Assets and Cultural Resources
  - The propagation of uncertainty and the lack of archaeological surveys in certain river sections.
- Agriculture, Land Use and Recreation
  - The agricultural land use analysis did not include evaluation of impacts to Pueblo and Tribal lands. The review is limited to operations that may affect about 53,000 acres of agricultural land along the Rio Chama, Central and San Acacia Sections, which represents less than 30 percent of the agricultural land in the Upper Rio Grande basin.
- Flood Control
  - New GIS-related tools have been developed since the source studies were done, so data other than the flow-damage relationship is unavailable. Some growth may have occurred since the initial study, and further growth is expected, such that the damages associated with specific frequency events will be higher than indicated. Future development would change potential damages from any flood event.
- Hydropower
  - Changes since the 1991 study will have to be quantified and applied to the existing condition analysis as well as each alternative. Future development in this context includes both demand within the region and the resulting impact upon prices.
- Environmental Justice
  - Population distributions and incomes may change with time, thereby changing the socioeconomic profile of the planning area.

Resource goals, mitigation measures, performance measures, and performance targets have also been evaluated in this EIS (Table 4-3). A comprehensive adaptive management plan would also include monitoring beneficial and adverse impacts, and determining mitigation effectiveness, for each of the resource areas.

Chapter V

Public Involvement, Consultation, and Coordination

1.1 Cooperating Agencies

The joint lead agencies (JLA) responsible for preparation of this Environmental Impact Statement (EIS)—U.S. Bureau of Reclamation (Reclamation), U.S. Army Corps of Engineers (Corps), and New Mexico Interstate Stream Commission—invited Federal agencies and local, State, and Tribal governments with appropriate expertise or jurisdiction in the planning area to participate in the National Environmental Policy Act (NEPA) process as cooperating agencies. Cooperating agencies signed formal agreements to commit resources to assist in this Water Operations Review (Review) and EIS. The cooperating agencies are the:

- Bureau of Indian Affairs
- U.S. Fish and Wildlife Service (FWS)
- New Mexico Department of Agriculture
- New Mexico Environment Department (NMED)
- Pueblo of San Juan

Technical experts from the JLA, cooperating agencies, and other interested agencies and organizations work together in technical teams and an Interdisciplinary NEPA Team to develop the technical aspects of the EIS. Project oversight and responsibility is the function of the Executive Committee, composed of local managing officials for the JLA (Figure 1-1). The Steering Committee facilitates coordination, information exchange, and technical guidance, with no formal decision-making role. More than 30 agencies and organizations contributed staff time in support of the Steering Committee and/or technical teams, in addition to the resources contributed by the cooperating agencies. Significant resources were invested by the New Mexico Department of Game and Fish (NMDGF), International Boundary and Water Commission-U.S. Section (USIBWC), Middle Rio Grande Conservancy District (MRGCD), City of Albuquerque, Rio Grande Restoration, City of Santa Fe, University of New Mexico, New Mexico State University, Sandia National Laboratories, New Mexico Water Resources Research Institute, and others.

1.2 Public Involvement

In preparation for broad-based public involvement, a Public Involvement Plan was finalized on September 30, 2000. Part of the implementation of the Public Involvement Plan included a market survey to solicit input from over 400 stakeholders in order to understand their issues and perceptions of the JLA, the NEPA process, and the Review and EIS. The survey was also used to obtain preferences for publicizing scoping meetings, information dissemination, and to gather stakeholder contact information to establish a mailing list. Additional public outreach efforts included newsletters, presentations to interested groups upon request, briefings for tribal governments, workshops and tours, press releases, public meetings to discuss progress, and establishment of a Website with meeting information and notes (http://www.spa.usace.army.mil/urgwops). All regularly scheduled technical team and Interdisciplinary NEPA Team meetings, as well as Steering Committee meetings, continue to be open to the public.

1.2.1 Public Scoping

The Notice of Intent (NOI) to prepare this EIS was published in the *Federal Register* on March 7, 2000. A news release announcing the NOI was sent to federal, tribal, state, and local officials; agency representatives; conservation organizations; news media; and others. The NOI and press releases to local newspapers also announced that a series of public scoping meetings would be conducted to obtain input on issues that should be considered in the EIS. Notice of the meetings was sent to approximately 400 individuals. The meetings were held in Colorado, New Mexico, and Texas in the evenings on the following dates and locations in 2000.

June 28, Alamosa, Colorado	September 20, Santa Fe, New Mexico
June 29, Taos, New Mexico	September 27, El Paso, Texas
July 26, Española, New Mexico	October 17, Las Cruces, New Mexico
August 9, Chama, New Mexico	October 18, Socorro, New Mexico
August 17, Albuquerque, New Mexico	

Project managers from each of the JLA were in attendance and one project manager gave a brief slide presentation on the goals and objectives for the Water Operations Review at each meeting. Each technical team was represented and staff was available to answer questions. Notes were taken at the meetings to document oral comments and are a part of the public record with the written comments. Interested or affected individuals, organizations and agencies were encouraged to submit written comments to the JLA to be most effectively considered. A total of 76 people, excluding members of the JLA, attended the public scoping meetings. Over 190 comments were documented from the written and oral comments submitted during and after the meetings.

All comments were reviewed and categorized according to their content. Questions and comments were passed along to the appropriate technical team for consideration. The report on the public scoping meetings (Appendix E) summarizes the categories and includes individual comments.

The main categories of comments received are shown in Appendix E and summarized in **Figure 5-1**. Because some comments were assigned to more than one category, the total of the comments categorized is greater than the total number of comments received.

1.2.2 Public Input for Alternatives Development

During the scoping process in 2000, meeting attendees expressed an interest in learning about the alternatives before they were finalized and analyzed in the EIS. In response, the JLA invited interested stakeholders to participate in the Review and EIS by identifying possible alternatives to be considered that would reflect the full range of operating flexibilities for water management along the upper Rio Grande. In addition to a Steering Committee meeting, 10 public meetings were held to discuss possible components of the alternatives and the strategy for developing them further in accordance with NEPA. The meetings on these draft alternatives were announced to more than 600 individuals and entities and publicized in the media. Attendance at the meetings ranged from 1 to 55 persons. The meetings were held on the following dates and locations in 2002.

January 15, Las Cruces, New Mexico	March 20, Santa Fe, New Mexico
January 16, El Paso, Texas	April 16, Española, New Mexico
February 5, Truth or Consequences, New Mexico	April 17, Abiquiu, New Mexico
February 6, Socorro, New Mexico	May 14, Alamosa, Colorado
March 19, Albuquerque, New Mexico	May 15, Pilar, New Mexico

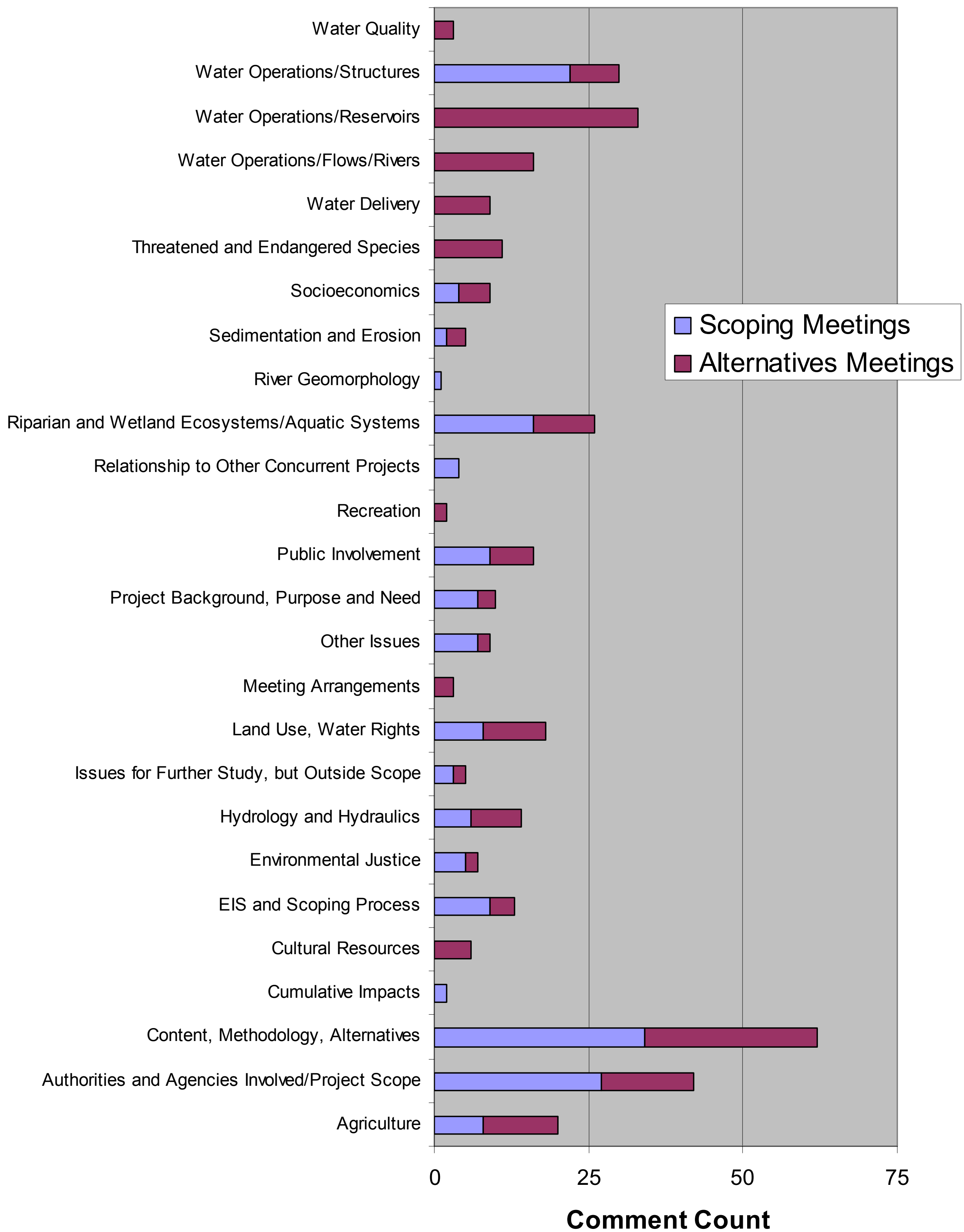
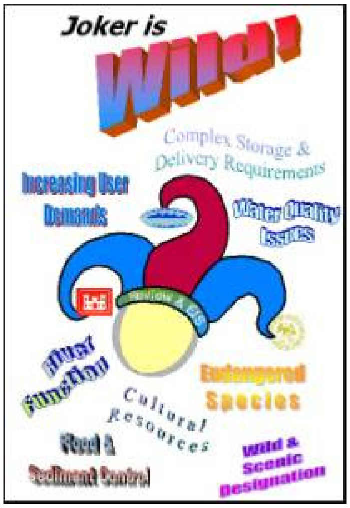


Figure 5-1. Comments Received during Public Scoping and Alternatives Meetings, Grouped by Category

Possible operational changes were discussed at the meetings, including ranges in reservoir water storage, channel capacity, flow bypass, and timing of waivers for carryover storage. The possible operational changes were explained using a playing card analogy to describe current operations and proposed draft operations changes. The cards "we hold" were described as the current operations (No Action) at each of the facilities. The cards "we want to play" were described as the components of the draft alternatives, the possible changes to water operations at specific facilities or in particular reaches of the river. Uncertainty was represented by two "wild" cards: one for variability of weather and runoff; the other, a "joker," to symbolize unplanned issues that may affect water management.



All comments were reviewed and categorized according to their content. The public input was used to help the technical teams formulate the alternatives to be analyzed in this EIS. Comments from the alternatives meetings are also summarized in Figure 5-1, grouped by main category. Some comments were assigned to more than one category, so the total of the comments categorized is greater than the total number of comments received.

1.2.3 Public Review of the Draft EIS

This draft EIS will be made available for a 60-day public review and comment period beginning January 20, 2006. During this public review period, the JLAs will host two workshops for interested Pueblo and Tribal leaders and technical staff, as well as nine public meetings at locations similar to those held previously during the project. The public meeting dates and locations will be included in the Notice of Availability of the EIS published in the Federal Register and in local and regional newspapers.

Approximately 150 copies of the draft EIS will be mailed to agency representatives, Pueblos and Tribes, and interested stakeholders who have expressed an interest in receiving a copy. In addition, over 200 letters will be sent to others on the Review mailing list to notify them of the availability of the draft EIS and enable them to request a copy if they wish. The draft EIS will be posted on the project Website (http://www.spa.usace.army.mil/urgwops/) and copies will be distributed to public libraries in the basin.

The initial distribution of the draft EIS or the draft EIS plus appendices will be sent to the Congressional delegation, 16 different federal agencies, 22 Pueblos or Tribes, 25 different state agencies or organizations under state authority, 4 local government agencies, and 8 stakeholder organizations.

1.3 Consultation with U.S. Fish and Wildlife Service

The Fish and Wildlife Coordination Act (16 U.S.C. §§ 661-667e, March 10, 1934, as amended 1946, 1958, 1978 and 1995) (FWCA) requires consultation with the U.S. Fish and Wildlife Service (USFWS) and the state wildlife resource agency where the "waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted . . . or otherwise controlled or modified" by any agency under a Federal permit or license. The purpose of this process is to promote conservation of wildlife resources, and to provide for the development and improvement of such resources in connection with the agency action (Digest of Federal Resource Laws of Interest to the U.S. Fish and Wildlife Service, http://laws.fws.gov/lawsdigest/fwcoord.html).

Coordination with the USFWS under the FWCA has included Planning Aid Letters, the most recent dated November 17, 2005 (see the end of Appendix L for a copy). A Draft Coordination Act Report was prepared by the action agencies and is undergoing internal review by the USFWS. The Coordination Act Report includes an estimate of the wildlife benefits or losses that will occur as a result of the proposed action and a description of conservation measures that should be adopted to obtain maximum overall project benefits.

Coordination and consultation under Section 7 of the Endangered Species Act will be conducted with the USFWS in connection with proposed future actions to implement+ the preferred alternative. For the Corps, such future actions may include revisions to existing water management agreements with the City of Albuquerque. For Reclamation, future actions may include modifications to the Low Flow Conveyance Channel.

1.4 Tribal Consultation and Coordination

Since the beginning of the Water Operations Review process, even before the NOI to develop an EIS was published, the JLA have recognized the sovereignty of tribes and pueblos that may be affected by changes in water operations and the Federal agency responsibility to protect Indian trust assets. The JLA discussed and planned for ways to encourage participation by the tribes and pueblos in the affected area, while recognizing the confidentiality of their resource data. Those targeted for specific outreach activities include the Navajo Nation and its chapters near the Rio Grande, Alamo and To'Ha'ji'lee; the Jicarilla Apache Tribe; the Mescalero Apache Tribe; and the Pueblos of Acoma, Cochiti, Isleta, Jemez, Laguna, Nambe, Picuris, Pojoaque, San Felipe, San Ildefonso, San Juan, Sandia, Santa Ana, Santa Clara, Santo Domingo, Taos, Tesuque, Ysleta del Sur, Zia, and Zuni.

In July 1999, a letter from the commanding officer of the Corps was sent to tribes, pueblos, and state and federal agencies to invite participation as formal cooperating agencies. The Pueblo of San Juan was the only Native American group to formally become a cooperating agency. In the Fall of 1999, a letter from the Reclamation Area Manager was sent to all tribes and pueblos to outline the scope of the proposed project and to open government-to-government consultations regarding potentially affected Indian trust assets, cultural resources, and any other pertinent issues. Other options for participation in the Review and EIS listed in the letter included involvement in the technical teams, Steering Committee, and Interdisciplinary NEPA Team either as full participants or as observers. The JLA has been open to suggestions from the pueblos and tribes on other ways that they would be interested in participating in the process.

Review project managers actively sought Native American involvement in the Water Operations Review by providing interactive briefings to tribal councils and pueblos governments, as well as to gatherings such as the All Indian Pueblo Council, the Eight Northern Indian Pueblos Council, Inc., and the Ten Southern Pueblos Governors Council, Inc. to provide information and gather input on the Review. Many of these briefings were arranged with the assistance of the co-chair of the Cultural Resources Technical Team who was designated as the San Juan Pueblo representative to that team. When technical teams needed information or input from a pueblo along the river, letters were sent from the Cultural Resources Technical Team to request information, feedback, or reviews of specific technical data. Technical teams considered pueblo water quality standards in the effects analysis where standards exist.

All tribes and pueblos have received an advance copy of this DEIS, and will be contacted to arrange consultation meetings to discuss the document and potential impacts on tribal lands. **Table 5-1** provides a brief summary of the number of briefings, letters, and teleconferences that were held with tribal groups between the beginning of 2000 and the issuance of this Draft EIS.

Table 5-1. Contacts with Tribal and Pueblo Officials and Groups by Year

Year	Contact Type	Number of Contacts
2000	Meeting	2
2001	Meeting	12
	Teleconference	2
2002	Correspondence	46
	Meeting	5
	Teleconference	1
2003	Correspondence	12
	Meeting	2
	Teleconference	1
2004	Correspondence	21
	Meeting	1
	Teleconference	0
July 2005	Correspondence	0
	Meeting	2
	Teleconference	0
	Government to Government Consultation	5

Chapter VI

Actions Identified But Outside The Scope Of The Review And EIS

6.1 Introduction

To complete the Upper Rio Grande Basin Water Operations Review (Review) and Environmental Impact Statement (EIS) within a reasonable amount of time, the joint lead agencies (JLA) limited its scope. The JLAs did not include facilities that had litigation in progress or actions that were not authorized by existing laws and regulations. Also not considered in the scope of the EIS were actions that would require specific water commitments or actions by others who did not participate in the Review and EIS. Alternatives that fell into these categories are described here. Most of these came up during public scoping, alternatives development, technical and Interdisciplinary Team meetings, or evaluation of alternatives.

Chapter 6 is intended to highlight water operations that may prove feasible and beneficial in improving system management after further planning and environmental studies are completed. Most of the actions described below require making changes in law, resolution of legal issues, obtaining permits, assuring environmental compliance, or securing some other required element necessary to implement. All will require a spirit of cooperation and sense of community among the various basin interests because further consideration will involve specific information on whose water is stored, how much, and for how long.

6.2 Within Existing Authorities But Outside Scope—No laws Need to Be Changed

6.2.1 Greater Utilization of Abiquiu Reservoir (Wet Water Bank)

6.2.1.1 Background

The Review and EIS evaluated alternatives to store native water up to 180,000 acre-feet (AF) in Abiquiu in a generic sense, without specifying ownership of the water being stored. An assumption in the planning model of the Upper Rio Grande Water Operations Model (URGWOM) was that releases from storage would be made in November and December that would minimize losses and could be kept constant across the alternatives. If November and December were the only time that any releases were made, then environmental compliance would be completed with the Review and EIS. This is not likely to be the case, however. There are opportunities to store and release for many purposes (if there is water to store, the Article 7 restriction is not in effect, and New Mexico is not in accrued debit). Storage is authorized in Abiquiu Reservoir up to the amount 200,000 AF for combined San Juan-Chama Project (SJC) water and Native Rio Grande water. However, during extreme flood conditions when downstream reservoirs are full, storage may exceed 200,000 AF. Current capacity in the authorized SJC pool is about 183,000 AF to elevation 6,220 feet, not 200,000 AF, due to sediment accumulation. The City of Albuquerque purchased flowage easements at Abiquiu Reservoir up to 6,220 feet. In 1987, the Corps reviewed the feasibility of purchasing additional flowage easements and concluded that it would not be cost-effective for any of the potential local sponsors (Corps 1987).

6.2.1.2 Opportunity

If there were a designated pool for storage of native water, together with SJC water storage authorized up to 200,000 AF total, the cooperators could actively schedule, store, and time releases to have the pool function for many purposes (e.g., as a wet water bank). Beneficial opportunities would include:

- Potential management of Compact deliveries by New Mexico by having a place to store water that is not needed to meet Compact obligations
- Potential conservation storage for the Rio Grande silvery minnow to comply with the Endangered Species Act
- Potential drought contingency storage
- Potential wet water bank for irrigation storage, Native American storage, acequia storage, municipal and industrial storage
- Potential increase of actual storage to 200,000 AF by acquiring additional reservoir flowage easements above 6,220 feet in elevation.

6.2.1.3 Limitations

The following limitations on establishing and utilizing storage of native water in Abiquiu Reservoir were identified.

- Requires permits from the Office of the State Engineer (OSE).
- Requires agreement with City of Albuquerque for storing within their easements.
- Requires water.
- Requires environmental compliance—an Environmental Assessment (EA) that could tier from this Review and EIS.
- Requires agreement among those who have water to store and those who have storage available on how the pool will be managed and administered.
- Additional easements and environmental compliance are required for storing above 6,220 feet elevation but not exceeding the authorized 200,000 AF of storage.
- Articles 6 and 7 of the Rio Grande Compact would occasionally limit upstream reservoir storage.

6.2.1.4 Possible First steps

1) Cooperate to determine specifics of who has water to store, for what purposes, and storage plans.
2) Determine with the City of Albuquerque what the terms for use of their flowage easements to store below 6220 feet.
3) Obtain permits from OSE.
4) Conduct EA to tier off of Review and EIS for evaluation of environmental effects.

5) Set up native water accounts in URGWOM. (SJC accounts are already included in URGWOM.)

6.2.2 Improving Watershed Conditions to improve water quality and quantity

6.2.2.1 Background

Quantity and quality of runoff that comes into the Rio Grande and the reservoirs can be improved by the health of the watersheds. The watersheds are outside of the direct control of the JLA.

6.2.2.2 Opportunity

There is, however, much to be gained in the basin by cooperating in efforts to improve upland conditions: improved water supply and water quality, reduced fire danger, slowing the spread of noxious weeds, etc.

A number of initiatives are in progress that agencies and the private sector could more actively support with people, information, education, and funding to implement plans already developed.

1. The multi-agency Southwest Strategy, Healthy Forests, and other initiatives
2. Middle Rio Grande Regional Water Planning Water Assembly
3. Jemez Y Sangre Regional Water Planning
4. Socorro-Sierra Regional Water Planning
5. Paso del Norte Watershed Council
6. New Mexico Acequia Association
7. Soil and Water Conservation Districts

6.2.2.3 Limitations

- Watershed planning usually requires non-federal match of federal funds.
- Federal funds for watershed programs are not always available.
- Requires visibility, extraordinary coordination efforts, and constant attention to keep viable.
- Requires university/private/federal/state/tribal/local partnering to be effective.
- Habits are hard to change.

6.2.2.4 Possible First Steps

1) Get the planners together.
2) Get the planners together with the funding programs, such as the U.S. Army Corps of Engineers (Corps) 729 Watershed Planning Program for filling data gaps, Bureau of Reclamation Irrigation Conservation and Efficiency Program, Natural Resources Conservation Service Watershed Planning Program.
3) Share information, data, and expertise.
4) Develop a communication and funding network for long-term progress.

6.2.3 Coordinate Water Supply Operations at Elephant Butte Reservoir and Caballo Reservoir with the Middle Rio Grande

6.2.3.1 Background

The Review and EIS scope did not include any water supply operations below Elephant Butte Reservoir. Improved communication and coordination, and flood control protocol resulted from the Review and EIS. Only flood control operations are in the URGWOM model in the Southern Section. Improved coordination and communication above and below Elephant Butte for water supply, as well, has potential to benefit both upstream and downstream sections.

6.2.3.2 Opportunity

- Time deliveries to Elephant Butte to reduce depletions
- Potentially reduce evaporation losses by storing in upstream reservoirs
- Work more closely with MRGCD water users and Reclamation to seasonally time diversions through the Low Flow Conveyance Channel to improve downstream deliveries with fewer losses.

6.2.3.3 Limitations

- Articles 6 and 7 of the Rio Grande Compact would occasionally limit upstream reservoir storage.
- Better understanding of losses through the San Acacia Section is needed.
- Shallow groundwater-surface water interaction data are needed to better define losses from Cochiti Dam to Elephant Butte.

6.2.3.4 Potential First Steps

1) Include people in the Southern Section with water to store when working out agreements to store in Abiquiu.
2) Coordinate annual operating plans that are developed both upstream and downstream from the April 1 forecast.
3) Update operation plans on a monthly basis and share information.
4) Support shallow groundwater/surface water data collection through the Central and San Acacia Sections.
5) Include water supply operations in the URGWOM model in the Southern Section.

6.3 Actions Outside Existing Laws, Authorizations, And Regulations

6.3.1 Storage of Rio Grande Water in Heron Reservoir

6.3.1.1 Background

Heron Reservoir is authorized solely to store SJC Project water as it is pumped through the tunnels from the Upper Colorado Basin. A small, temporary pool (from 6,000 to 10,000 AF) of Native Rio Grande water may be useful for short-term benefit when certain situations arise.

6.3.1.2 Opportunity

- Could be used for drought contingency.
- Acequias could have some storage available to stretch low runoff through an irrigation season.
- An entity could take delivery of their SJC water at Heron.

6.3.1.3 Limitations

- Requires changes in the law authorizing Heron Reservoir.
- Requires approval of the three Rio Grande Compact Commissioners.
- If and when space is needed to receive initial deliveries of San Juan-Chama Project water, the space would have to be evacuated (Pueblo Reservoir on the Arkansas River in Colorado does this).

6.3.1.4 Potential First Steps

1) Rewrite some water conservation accounts, and losses in the URGWOM model; revise URGWOM rule set and run the model to understand the hydrologic effects and secure Compact support.

2) Depending on the outcome of Step 1, undertake planning and environmental compliance studies for authorization change.

6.3.2 Use of Cochiti Lake for Other than Authorized Purposes

6.3.2.1 Background

There have been many proposed actions for Cochiti Dam and Lake that are outside of existing authorities. The management of lands associated with Cochiti Dam and Lake are held in trust by the United States for the beneficial owners, the Pueblo de Cochiti, a federally recognized Native American Tribe. As a result of its Native American Trust responsibilities, the Corps is required to protect Cochiti natural and cultural assets. The Corps and the Pueblo de Cochiti are conducting an array of studies that are intended to characterize the interactions of Cochiti Dam and Lake with Tribal and other resources. The studies will provide a baseline against which the impacts of future operational changes at the lake may be evaluated.

6.3.3 Use of Jemez Canyon Dam for other than Authorized Purposes

6.3.3.1 Background

Jemez Canyon Dam is authorized for flood and sediment control. Water stored permanently for other than these authorized purposes require a law change and environmental compliance. There have been previous water storage agreements that stored water in Jemez Canyon. One expired in 2000 and the Reservoir was evacuated. In 2002, an agreement between the Pueblo of Santa Ana and the State of New Mexico was made to temporarily store water in Jemez Canyon under a deviation in operations approved by the Corps of Engineers. There are no agreements currently in place. Jemez Canyon Dam is on Pueblo of Santa Ana land and the Corps has Native American trust responsibilities with respect to any changes in actions at Jemez Canyon Dam.

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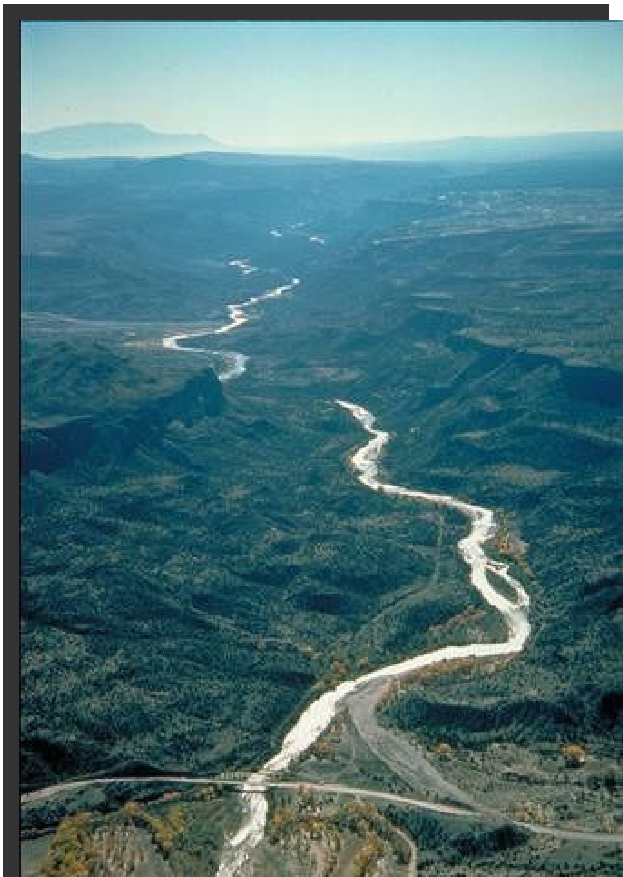
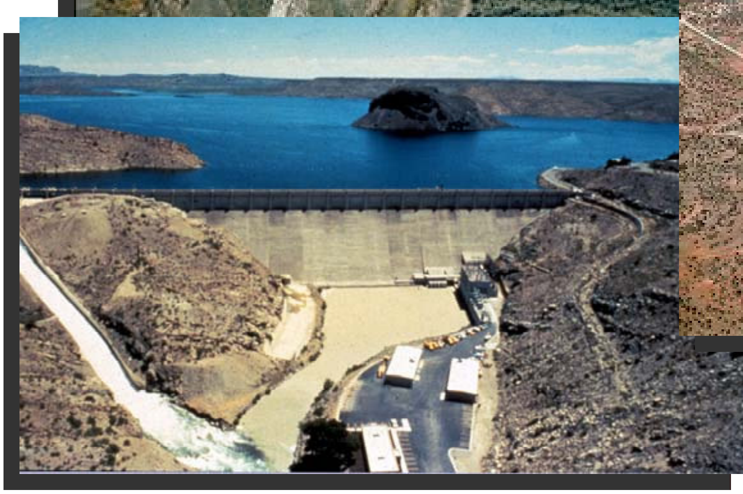


U.S. Army Corps of Engineers,
Albuquerque District

U.S. Department of the Interior,
Bureau of Reclamation

New Mexico
Interstate Stream Commission



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APPENDIX B
QUALITY ASSURANCE PLAN

Table of Contents

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1.0 QUALITY ASSURANCE

1.1 INFORMATION

Project Title: Upper Rio Grande Basin Water Operations Review & EIS

Location of Project: Upper Rio Grande Basin (Basin), Headwaters in Colorado through all of New Mexico to Fort Quitman, Texas

Joint Lead Agencies: U.S. Army Corps of Engineers (COE), Albuquerque District, NM

Bureau of Reclamation (BOR), Albuquerque Area Office, NM

New Mexico Interstate Stream Commission (NMISC), Santa Fe

Project Description: The Joint Lead Agencies (JLA) are considering the modification of river and reservoir operations within the Upper Rio Grande Basin. The Basin includes the Rio Grande COE and BOR facilities above Fort Quitman, Texas. The JLA are initiating an Upper Rio Grande Basin Water Operations Review (Review), which will result in the development of an integrated plan for the federal and state operations that affect rivers and reservoirs in the Basin. The Upper Rio Grande Water Operations Model (URGWOM) will be used as a primary tool for developing alternative water operations and evaluating their impacts. To ensure compliance with applicable federal and state legislation affecting the Basin, the JLA will prepare the Programmatic Water Operations Environmental Impact Statement (Water Operations EIS) that comprehensively addresses the proposed action and all reasonable alternatives.

Project Organization Chart and Roster: The Organization Chart for the Review and related Water Operations EIS is shown in **Figure 3-1** of this Work Plan and in Figure 1 of the Memorandum of Agreement (MOA) between the JLA. It shows the decision-makers and the Executive Committee makeup. The Management Team is indicated in the figure, as well as the other working parts of the organization. The rosters of most of the parts of the organization are provided in **Table 6.1**. This table also provides the list of the contractors used in this project. Appendix C of this Work Plan provides the vita of all individuals listed in **Table 6.1**.

1.2 REFERENCES

Memorandum of Agreement: Upper Rio Grande Basin Water Operations, January 26, 2000.

Work Plan for the Rio Grande Basin Water Operations Review: U.S. Army Corps of Engineers, Albuquerque District, Contract # DACA47-97-D-0009, Delivery Order #2, January 26, 2000.

Quality Control Plans: CESPD R 1110-1-8, APP C, 14 December 1998. Pages C-8 and C-9 provide the minimum requirements for quality assurance. The following subsections of this Section provide the details developed at the technical review strategy sessions and during the complex planning process for the Review and Water Operations EIS.

JLA References: APPENDIX A to this Work Plan, "Environmental Laws and Regulations", provides the list of the required references for the Review and Water Operations EIS. Appendix A of the MOA provides the water operations authorities.

Hydrologic Modeling Quality Control Plan: CADSWES has provided the hydrologic modeling quality assurance plan for the standard operating procedure for use of RiverWare. This modeling quality assurance provides a synopsis of the philosophy of computer modeling, a brief overview of staff responsibilities and hardware and software requirements, and the applicable educational and training needs for the modeling effort.

Other Modeling Software (Current Versions): FLO-2D, (Users Manual, Model Verification Document), is a finite element, 2-dimensional flood routing model. The Water Operations Review and EIS version of this program translates flows into depths and velocities for use in riparian and cultural resource evaluations in the Basin. The version of the FLO-2D model for the Water Operations Review and EIS was developed by Jim O'Brien of Tetra Tech.

RMA-2, (SMS Reference Manual) is a 2-dimensional module of the Surface Modeling System (SMS) developed by Brigham Young University in cooperation with the U.S. Army Corps of Engineers Waterways Experiment Station (WES). The Water Operations Review and EIS version of RMA-2 with inputs of appropriate data for specific reaches of the Rio Grande, supports sub-critical flow analysis, including wetting and drying for use in riverine aquatic evaluation.

HEC-RAS, (Users Manual), is a 1-dimensional, step backwater, hydraulic program used mostly for floodplain and flood depth determination. HEC-2 (Hydraulic Reference Manual, Users Manual and Applications Guide) is a surface water profile model. The U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) developed both HEC-RAS and HEC-2. These canned programs will be customized to use Rio Grande cross-section, roughness, and other applicable data from specific reaches of the Rio Grande for evaluation of peak instantaneous discharge effects.

Hydraulic Design Package for Channels (SAM Users Manual), the basic model provides the computational capability to include processes of erosion, entrainment, transportation and deposition of sediments in the design of stable channels and was developed at WES. Using sediment samples and other data pertinent to specific sites along the Rio Grande, the Water Operations review and EIS version of SAM will aid in identifying erosion and other sediment effects of flow changes.

Data: U.S. Geological Survey National handbook of recommended methods for water data acquisition. EPA Environmental Investigations Standard Operating Procedures and Quality Assurance Manual.

Metadata: Federal Geographic Data Committee (FGDC) "content Standards for Spatial Metadata" (FGDC-STD-001-1998), Administrative Records Manual developed for the Review and Water Operations EIS.

1.3 APPLICABILITY AND OBJECTIVE

1.3.1 Quality Assurance Plan

This Quality Assurance Plan applies to all activities involved with this project. The objective of this Quality Assurance Plan is to provide the JLA with a management tool that will help achieve the maximum in high quality products and services from the Management Team, the Interdisciplinary (ID) NEPA Team, the Resource Teams, the Support Teams, and the contractors.

1.3.2 Quality Assurance Tools

Project quality and performance will be enhanced by the use of quality tools available for the project. These are summarized below:

GIS Mapping Systems Software: GIS analysts, in order to construct geographic data based maps and figures will use ARC/INFO Export Files, Arc View Shape Files, AutoCAD Drawing Exchange Files and associated software. Basic guidelines have been developed for the Technical Teams when assessing potential date types and sources. Databases will be developed or linked to store a vast amount of data necessary to develop and maintain URGWOM and other required models that analyze various parameters of the Basin.

Modeling Software: URGWOM (Upper Rio Grande Water Operations Model) is a unified water operations model for the Basin. This model is a cooperative effort of six federal agencies and others for simulating water storage and delivery operations in the Rio Grande from its headwaters in Colorado to Fort Quitman, Texas. The model will be used in flood control operations and water accounting. A planning version will be used in evaluating water operations alternatives. Software that is used for other resource parameters will be used as appropriate.

Cost/Schedule Tracking Software: Open Plan project management software is utilized to track costs and monitor schedules.

Lessons Learned: Lessons learned from similar projects will be incorporated throughout the completion of the Review and Water Operations EIS. In particular, similar water operation studies, metadata bases, and database presentational tools were evaluated during the preparation of this Work Plan. Also, other environmental resource information will be used to prepare the Draft EIS (DEIS) associated with the combined proposed water operations for the future.

1.3.3 Quality Review Procedures

The comprehensive review process for the Review and Water Operations EIS will include the following:

- Quality Control Check: Each task product will be subject to one or more quality control checks prior to submittal. Each Team Leader or other competent project team member designated by the Management Team shown in Figure 3.1 of this Work Plan typically will perform the quality control checks. The quality control checks will be performed to ensure that the performance of the work conforms to appropriate technical criteria, and meets the MOA between the COE, BOR, and the NMISC.
- Peer Review: A competent in-house scientist or engineer, prior to formal submittal for independent technical review, will review each task product. Typically, the ID NEPA Team or a Technical Advisor will be assigned this review by the Management Team. It will be conducted prior to review by the Independent Technical Review Team or by the Steering Committee.
- Independent Technical Review: Formal independent technical reviews will be conducted prior to the Executive Committee's submittal of the Task products during the public review process. Reviewers will include those agencies or individuals listed in Table 5-1 of this Work Plan. Communication between the Independent Technical Review Team and the Project Steering Committee will be ongoing throughout the task product preparation process; however, members of the Independent Technical Review Team will not perform the work associated with each task's product.
- Documents Scheduled for Review: The following documents are anticipated for quality control checks, peer review, and independent technical review during the course of the project.

- Support Team Products: The URGWOM Integration/Water Operations, GIS, and Hydrology & Hydraulics support teams will produce a technical document for use with the Review and Water Operations EIS process. These documents will be completely reviewed before they are distributed with the DEIS to the public.
- Resource Team Products: Each of the six resource teams (river morphology, sedimentation, & mechanics; riparian & wetland ecosystems; cultural resources; aquatic systems; water quality; recreation, land use, socio-economics, & environmental justice—these titles of the teams might have been changed?) will produce a technical document for use in the Review and Water Operations EIS. These documents will be completely reviewed before they are distributed with the DEIS to the public.
- The DEIS will be developed by the Interdisciplinary NEPA Team and it will be reviewed internally by the Management Team advisors and externally by the Independent Technical Review Team. The document will be distributed to the public for review.

1.3.4 Project Coordination

Coordination is essential for the successful completion of the Review and Water Operations EIS. Key team members will be involved with coordination activities to ensure effective communications, maintenance of interdisciplinary structure, resolution of potential conflicts, and adherence to schedule and cost requirements as required in the MOA. Specific responsibilities are outlined in the following subsections of this Section, in the MOA, and throughout the rest of this Work Plan.

1.3.5 Implementation of Work Plan

The Executive Committee and its Management Team are responsible for the Review and Water Operations EIS schedule and costs, and shall serve as the liaison with the "Decision Makers" of the COE, BOR, and the NMISC. The Management Team shall be responsible for implementation of this Quality Assurance as shown in **Figure 3.1** of this Work Plan and in Figure 1 of the MOA. The Executive Committee must approve deviations from this Quality Assurance Plan as indicated in the MOA.

APPENDIX C
GLOSSARY OF TECHNICAL TERMS

Glossary

Acequia—A system of community irrigation ditches and diversions adjacent to a river, often using natural materials such as rocks and brush for diversion structures.

Acre days—The number of acres covered by overbank flooding times the duration in days.

Acre foot—A volume of water that covers 1 acre to a depth of 1 foot (43,560 cubic feet, 1,234 cubic meters, 325,851 gallons).

Active capacity—The volume of space available for active conservation plus exclusive flood control pools.

Aggradation—A geologic process where streambeds and floodplains and the bottom of water bodies are raised in elevation by the addition of material; the opposite of degradation.

Annual mean discharge—The average or mean of the daily mean discharges for the water year.

Annual operating plan—A document that defines likely reservoir operations for a given year based on snow melt runoff forecasts and estimated demands.

Annual peak discharge—The maximum instantaneous discharge that occurs during an individual water year.

Armoring—(a) The natural process in which an erosion-resistant layer of relatively large particles is formed on a stream bed or bank due to the removal of finer particles by the flow; (b) Placement of a covering on a stream bank to prevent erosion; (c) Vegetative growth covering the channel bed or banks.

Avulsion—A sudden or abrupt change in course of a stream channel usually associated with the stream breaking through its banks during a flood.

Bankfull channel width—The distance across the channel between the tops of the left and right banks at the elevation of the floodplain, measured at right angles to the longitudinal flow direction.

Bankfull discharge—The maximum discharge that a channel is capable of transmitting without overtopping its banks (i.e., the channel capacity). Also, bankfull discharge is considered to be the discharge at which the floodplain experiences incipient flooding. In self-adjusted alluvial channels that are in a state of dynamic equilibrium with the imposed water and sediment supply and that are bounded by a self-formed floodplain, the magnitude of the bankfull discharge is often assumed to be about the same as the mean annual flood peak (recurrence interval of 1.5 to 2.33 years), although recurrence intervals for the bankfull discharge of 1 to 25 years have been reported in the literature.

Bed load—The portion of the total sediment discharge that moves in contact with the bed by rolling, sliding, or saltation.

Bed Material—Sediment material found in the bed of a stream in appreciable quantities.

Bed Material Load—The portion of the total sediment discharge that is composed of particle sizes that are commonly found in the bed; mobilized by flowing water; and may be transported either in suspension or as bed load. This portion of the total sediment discharge is related to the flow and sediment characteristics of the bed, and is generally carried at the capacity of the stream.

Bypass—(a) To allow flow through its natural course at a diversion structure; (b) water that remains in its natural course undiverted.

Capacity—The maximum volume of available space.

Carryover storage—Water held in storage until a specified time for release.

Channel aggradation—The raising of the channel bed through deposition of sediment by flowing water.

Channel capacity—The normal (non-emergency) operations maximum flow in a channel, usually set by analysis and policy.

Channel degradation—Lowering of the channel bed through removal of sediment by the flowing water.

Channel forming discharge—A theoretical discharge that, if constantly maintained in an alluvial stream over a long period of time, would produce the same channel geometry that is produced by the long-term variable runoff hydrograph. Various surrogates for the channel-forming discharge are often used to facilitate geomorphic analysis. The most common are bankfull discharge; a specific interval from the annual peak or partial duration frequency curves (e.g., 1.5-year peak discharge); and the effective discharge.

Confluence—The intersection of two or more water courses.

Conservation capacity—The volume that the conservation pool can hold.

Conservation pool—The space allocated for all normal uses, bounded below by inactive pool and above by exclusive flood control pool or joint use pool.

Daily mean discharge—Commonly, the mean of the 15-minute discharges for the 24-hour period of a day.

Daily mean flow—The flow in cfs amounting to the total volume of water for the 24-hour period (i.e., the average flow for the day).

Degradaton—A geologic process where the elevation of streambeds, sandbars and floodplains is lowered by erosion; the opposite of aggradation.

Deposition—The material settling out of water into a streambed. Occurs when the energy of the flowing water is unable to support the load of suspended sediment.

Designated flood frequency—The probability that a flood will occur in a given year (usually 20, 10, or 1 percent).

Dissolved oxygen (DO)—The amount of free oxygen found in water; usually the most commonly employed measurement of water quality. Low DO levels adversely affect fish and other aquatic life. The ideal dissolved oxygen for fish life is between 7 and 9 mg/L. Most fish cannot survive when DO falls below 3 mg/L.

Diversion—A controlled amount of water taken out of the main channel and transported elsewhere.

Effective discharge—The incremental discharge that transports the largest percentage of bed material over the long-term. In self-adjusted alluvial streams that are in a state of dynamic equilibrium with the imposed water and sediment supply, the magnitudes of the effective discharge and bankfull discharge are usually similar.

Endangered species—A species of subspecies whose survival is in danger of extinction throughout all or a significant portion of its range.

Entrainment—The process by which aquatic organisms, suspended in water, are involuntarily carried by the motion of water.

Exceedance probability—The probability that a random hydrologic event will exceed a given magnitude, expressed in percent. For flood frequency curves, the exceedance probability is the reciprocal of the recurrence interval. For example, the 100-year flood has a 1-percent chance, on average, of being equaled or exceeded in any given year.

Extirpated species—A species of plant of animal that is no longer found in a given area.

Firm yield—The amount of water that can be provided by a basin and reservoir system with reasonable certainty each year. For the San Juan-Chama Project including Heron Reservoir, it is 96,200 acre-feet each year.

Flood control pool—The pool from top of active conservation to the top of total capacity, exclusively for flood storage.

Flood frequency—Synonymous with Recurrence Interval.

Floodplain—The relatively flat area adjoining a river channel that is constructed by vertical and lateral accretion processes of the river in the present climate and that is overtopped during times of high discharge when the bankfull capacity of the channel is exceeded.

Flow duration curve—The cumulative distribution function that represents the percentage of time that a specified discharge is equaled or exceeded. Flow duration curves are generally based on the daily mean discharge.

Gain—The addition of water not accounted for upstream.

Geomorphologic—Of or related to the configuration of landforms and earth features.

Hydraulic geometry—A general term used to characterize the relationships between discharge and the channel morphology, hydraulics, and sediment transport in an alluvial channel. The relationships are usually expressed in the form of power functions of discharge as a function of width, depth, and velocity.

Hydraulic height—Height to which water rises behind the dam, the difference between the lowest point in the original streambed and the maximum water surface.

Hydraulic routing—The mathematical technique for relating inflow and outflow hydrographs using both continuity and momentum equations.

Hydrograph—A graph showing the flow of water with respect to time for a given point on a channel.

Hydrologic Routing—The mathematical technique for relating inflow and outflow hydrographs using continuity equation and analytical or assumed storage/release relationship.

Imported waters—Waters from another basin, also known as “transbasin”, “transmountain”, or, in this case, “SJ-C”.

Incidental benefits—After the primary purpose for releasing water is satisfied, other benefits are realized from the use of the water. Examples are fishery flows and rafting releases that arise out of the irrigation releases.

Inundation—Flooding 6 inches or more above the land surface.

Lag—The time for water in a channel to get from one known point to another downstream.

Lake evaporation—The evaporation measured from a standard pan multiplied by a pan coefficient to more closely match actual evaporation from the lake.

Lateral migration—Movement of the channel in a direction that is generally perpendicular to the general down-valley flow direction due to erosion of the channel banks.

Longitudinal stream profile—A profile of elevation versus linear distance along a river reach, usually representing the minimum elevation in the channel cross-section, also known as the thalweg (see “thalweg”).

Loss—The reduction in quantity of water in transit not attributable to intended removal such as diversion. Also used to denote reservoir loss for present, hypothetical, and pre-reservoir conditions.

Mean annual discharge—The average or mean of the annual mean discharge for more than one water year or for the period of record.

Morphology—Shape and physical characteristics of the river.

Native water—Water from precipitation or other sources within the basin. Also known as "Natural", "Rio Grande", and "RG".

Natural—(See “native water”.)

Non-exceedance probability—The probability that a random hydrologic event will not exceed a given magnitude, expressed in percent.

Non-vegetated channel—The main channel of a river that conveys the bulk of the annual mean discharge and is generally devoid of perennial vegetation.

Outlet works—A feature of a dam used to regulate releases usually for flows within the downstream safe channel capacity.

Overbank—The area of a floodplain covered by floodwater overflowing its banks.

Planform—The shape or horizontal pattern of a river when viewed from above.

Pool—A named physical space within a reservoir of a similarly named capacity, with defined upper and lower elevation boundaries. Example: The "active conservation pool" has a capacity of the "active conservation capacity".

Probable maximum flood (PMF)—The largest flood reasonably expected at a point on a stream because of a probable maximum storm and favorable runoff conditions.

Recurrence interval—The average time interval, over the long term, between occurrences of a hydrologic event. For example, the 100-year peak discharge is the instantaneous annual peak discharge that, on average, is equaled or exceeded once every 100 years.

Reservoir inflow—The amount of water entering a reservoir expressed in acre-feet per day or cubic feet per second.

Riparian—The area along the banks of a waterway, including the associated soils, vegetation and wildlife.

River cross-section geometry—A distance-elevation relationship depicting the shape of the ground surface across the channel, perpendicular to the flow direction. The convention among hydraulic engineers, hydrologists, and geomorphologists is to plot the relation from left to right bank looking downstream.

Routing—The mathematical technique for relating inflow and outflow hydrographs, most often used for flood waves.

Rule—A user specified macro-algorithm defining an operational constraint or requirement. Usually included in groups that are ordered by priority. Used in reference to URGWOM.

Run of the river—An operational philosophy placing low priority on power generation, requiring releases to be driven by other purposes first.

Scour—A localized lowering of the channel bed from the removal of bed material due to turbulence caused by an obstruction or hard point in the channel such as bridge piers and abutments, rock jetties, and bedrock outcrops.

Sediment pool—The reservoir space allocated for sediment deposition.

Seepage—The slow movement or percolation of water through small cracks, pores, and interstices from an embankment, abutment, or foundation.

Stage-discharge relationship—The relationship between the height of the water-surface above an arbitrary or known datum and the discharge at that water-surface.

Steering committee—The interagency group responsible for direction, management, and budget support for this Water Operations Review and EIS.

Storage—The quantity of water in a specified space.

Suspended Sediment Load—The portion of the total sediment discharge that moves in suspension in the water column.

Temporal—Relating to a transient event, usually short in duration.

Thalweg—The line connecting the lowest points along a channel bed.

Threatened species—A species of plant or animal that has the potential of becoming endangered in the near future.

Time step—The chosen time increment for the model run.

Top of dam—The elevation of the uppermost surface of a dam, usually a road or walkway, excluding an parapet wall, railing, or curb.

Total capacity—The total amount of available storage, equaling live capacity plus dead capacity.

Total sediment discharge—The total quantity of sediment that passes a cross section of the river over a specified unit of time. The total sediment discharge is the composite of suspended sediment load and bed load. It is also the combination of the bed material load and wash load.

Transbasin diversion—Water imported from one basin to another or across the continental divide. Also known as "San Juan-Chama", "SJ-C", and "transmountain" water.

URGWOM (Upper Rio Grande Water Operations Model)—Includes four different types of models: Forecasting, Water Operations, Accounting, and Planning. The model of the upper and middle Rio Grande from the Colorado headwaters and San Juan-Chama diversions down to Fort Quitman, Texas.

Water accounting—After-the-fact reconciliation and operational planning of water movements and deliveries.

Water operations—Planning, scheduling, and delivering water from reservoir storage and releases for all usage, safety, and environmental purposes.

Water ownership—The recognition of allocations, storages, and deliveries of water as property of an entity.

Water types—A concept of the division of water as derived from multiple sources, in this case; SJ-C and RG waters.

Wild and Scenic—A reach of river protected from commercial development that is tightly managed to retain its natural state to the greatest extent possible.

APPENDIX D
MEMORANDUM OF AGREEMENT

MEMORANDUM OF AGREEMENT
UPPER RIO GRANDE BASIN WATER OPERATIONS

I. INTRODUCTION

The Bureau of Reclamation ("BOR"), the U. S Army Corps of Engineers ("COE"), and the New Mexico Interstate Stream Commission ("NMISC"), collectively referred to as the "signatories" or "lead agencies", enter into this Memorandum of Agreement (this "Agreement") to conduct the Upper Rio Grande Basin Water Operations Review (the "Review") and prepare a Programmatic Water Operations Environmental Impact Statement ("Water Operations EIS"). The Review and Water Operations EIS are sometimes collectively referred to herein as the "project". The Review will be the basis of, and integral to, the Water Operations EIS. The Water Operations EIS will be prepared by the parties in accordance with the National Environmental Policy Act ("NEPA") and will present alternatives for the exercise of discretionary authority of BOR, COE, and NMISC with respect to water operations at federally-operated facilities in the upper Rio Grande Basin ("Upper Rio Grande Basin Water Operations") and evaluate the environmental, economic, and social effects of these alternatives. The parties acknowledge and agree that collective federal discretionary actions taken with respect to Upper Rio Grande Basin Water Operations constitute a major federal action significantly affecting the quality of the human environment. BOR, COE, and NMISC are joint-lead agencies in complying with analysis, documentation, and disclosure requirements of the NEPA process.

The project will consider the means available to exercise existing water operations authorities of BOR, COE, and NMISC with respect to Upper Rio Grande Water Operations to (1) meet agricultural, domestic, municipal, industrial, and environmental water needs, including water needs for the conservation of endangered and threatened species as required by law, consistent with the allocation of supplies and priority of water rights under state law; (2) meet downstream water delivery requirements mandated by the Rio Grande Compact and international treaty; (3) provide flood protection and sediment control; (4) assure safe dam operations; (5) support compliance with local, state, federal, and tribal water quality regulations; (6) increase system efficiency; and (7) support compliance of BOR and COE with the National Environmental Policy Act ("NEPA") for Upper Rio Grande Basin Water Operations and activities and support compliance of all signatories with the Endangered Species Act (the "ESA").

BOR and COE operate reservoir and water conveyance facilities under a number of different authorities, contracts, and policies. NMISC is authorized to protect, conserve and develop the waters of the state and monitors operations at reservoirs and water conveyance facilities for these purposes and to assure compliance with the Rio Grande Compact. The Review and related Water Operations EIS will define procedures and protocols for review, coordination, consultation, and public input in water operations decisions. The decision-making process must be flexible and efficient to allow water managers to be responsive to ever-changing conditions, but must also be designed to allow public review and input.

Subject to applicable compacts and decrees, the State of New Mexico administers water rights within the state. Nothing in this Agreement, the Review, or the Water Operations EIS shall be construed to create water rights or require the State of New Mexico to grant water rights to any entity. Further, this Agreement shall not be construed as a *de facto* negotiation of water rights or authority to create depletions that negatively impact water users or compact deliveries. The foregoing shall not limit or otherwise affect the existing authorities of BOR, COE and NMISC that are the subject of the Review and the Water Operations EIS.

II. PURPOSE OF THE AGREEMENT

The purpose of this Agreement is to define the scope of the project and to establish the roles and responsibilities of the signatories relating to completing the Review and associated Water Operations EIS in accordance with NEPA and the ESA, and relevant regulations.

III. PURPOSE AND NEED STATEMENT FOR THE PROJECT

The signatories adopt the following purpose and need statement for the project:

The proposed action is the adoption of an integrated plan for water operations at existing COE and BOR facilities in the Rio Grande basin above Fort Quitman, Texas.

Need: Under various existing legal authorities, and subject to allocation of supplies and priority of water rights under state law, the COE and BOR operate dams, reservoirs, and other facilities in the upper Rio Grande basin to:

(1) store and deliver water for agricultural, domestic, municipal, industrial, and environmental uses;

(2) assist the ISC in meeting downstream water delivery obligations mandated by the Rio Grande Compact;

(3) provide flood protection and sediment control; and

(4) comply with existing law, contract obligations, and international treaty.

Purpose: The Upper Rio Grande Basin Water Operations Review will be the basis of, and integral to, preparation of the Water Operations EIS. The purpose of the Review and Water Operations EIS is to:

(1) identify flexibilities in operation of federal reservoirs and facilities in the upper Rio Grande basin that are within existing authorities of COE, BOR, and NMISC, and in compliance with state and federal law;

(2) develop a better understanding of how these facilities could be operated more efficiently and effectively as an integrated system;

(3) formulate a plan for future water operations at these facilities that is within the existing authorities of BOR, COE, and NMISC; complies with state, federal, and other applicable laws and regulations; and assures continued safe dam operations;

(4) improve processes for making decisions about water operations through better interagency communications and coordination, and facilitation of public review and input; and

(5) support compliance of the COE, BOR, and NMISC with applicable law and regulations, including but not limited to the National Environmental Policy Act and the Endangered Species Act.

IV. SCOPE

The Review and Water Operations EIS will address water operations at the following facilities with the noted exceptions and limitations. The term "water operations," as used in this Agreement, shall mean and refer to physical operation of the identified facilities.

- Flood control operations at Platoro Reservoir (the Review and Water Operations EIS will include only flood control operations at Platoro that are under COE authority. None of the signatories to this Agreement have authority over water supply operations at Platoro).
- Closed Basin Division -- San Luis Valley Project
- Heron Dam and Reservoir
- Abiquiu Dam and Reservoir
- Cochiti Dam and Reservoir
- Jemez Canyon Dam and Reservoir
- Low Flow Conveyance Channel
- Flood control operations at Elephant Butte Dam and Reservoir (because of current litigation, water supply operations at Elephant Butte will not be included in the Review or the Water Operations EIS).
- Flood control operations at Caballo Dam and Reservoir (because of current litigation, water supply operations at Caballo will not be included in the Review or the Water Operations EIS).

BOR and COE operate these facilities under federal authorities, state water rights permits, and various contracts. The Review and Water Operations EIS will be limited to actions that can be implemented within the existing authorities of the signatories in compliance with applicable international, federal, state, and tribal laws, regulations, and contracts, including without limitation the Rio Grande Compact. A summary of important pertinent authorities and legal constraints is provided for reference in Appendix A.

V. ORGANIZATION TO ACCOMPLISH THE PROJECT

The organization for the preparation of the Water Operations EIS will include cooperating agencies and stakeholders (sometimes hereinafter referred to as the "EIS parties"). Cooperating agencies are those agencies that have or will enter into an agreement with the lead agencies in support of the project pursuant to Article VII. The organizational structure is shown schematically in Figure 1. In accordance with NEPA and Council on Environmental Quality ("CEQ") implementing regulations, an interdisciplinary team will be organized to conduct required technical work and prepare the Water Operations EIS. Support to the joint lead agencies will be provided by the EIS parties through participation on the Steering Committee, interdisciplinary NEPA team, and technical teams.

A. Final decisions. Except as otherwise specifically provided herein, the lead agencies are collectively responsible for all decisions relating to the Water Operations EIS and will make all final decisions on disputes arising during the NEPA process.

For disputes involving different interpretations of information, the lead agencies agree to consider different interpretations if such interpretations are supported by sufficient credible data, as determined by the lead agencies. For other disputes, the EIS parties will make all reasonable efforts to resolve issues in a collaborative and timely manner. If a disputed issue cannot be resolved in a collaborative and timely manner, the lead agencies will make a final decision. This Agreement and any related agreements supporting the purpose of this Agreement shall not limit or in any way affect any person or entity's right to comment or otherwise participate in the normal public review and comment process.

B. Decision makers. Each of the lead agencies shall designate a decision maker. The decision makers collectively have authority to conduct the project and each of the lead agencies hereby represents that the decision maker specified below is authorized to act on behalf of the agency with respect to matters relating to the Water Operations EIS, including without limitation the authority to sign any resulting Record of Decision. During the process, the decision makers will attempt to resolve any conflicts or disputes that cannot be resolved by the executive committee. The decision maker for the BOR is the Regional Director, Upper Colorado Region. The decision maker for the COE is the Division Engineer South Pacific Division. The decision maker for the NMISC is the New Mexico Interstate Stream Commission.

C. Executive committee. The executive committee shall have overall responsibility for accomplishing the project by allocating staff and funding resources, providing guidance to staff, reviewing progress, and coordinating among signatory agencies. The executive committee will select and retain a mediator or facilitator to assist in resolving disputes or conflicts at all levels. The executive committee will assist in resolving any disputes or conflicts referred by the management team or the interdisciplinary NEPA team. Disputes or conflicts that cannot be resolved by the executive committee will be referred to the decision makers. The decision makers may direct that the dispute or conflict be resolved by mediation. Membership of the executive committee shall consist of the District Engineer, Albuquerque District, U.S. Army Corps of Engineers; Area Manager, Albuquerque Area Office, Bureau of Reclamation; and the Interstate Stream Engineer for the NMISC; or their delegates. Appendix B contains the charter of the executive committee.

D. Steering committee. The executive committee will establish a Steering Committee to provide direct communication between the executive committee and representatives of cooperating agencies and key stakeholders that will be identified by the executive committee. The purpose of the Steering Committee is to facilitate coordination and information exchange. The Steering Committee will have no decision-making role. Appendix C contains the charter of the Steering Committee.

E. Management Team. The management team shall be responsible for day-to-day project management. Each signatory (lead) agency shall assign one member to the management team. The management team will have primary responsibility for:

- Overall coordination of project activities
- Formation of an interdisciplinary NEPA team and supporting technical work teams
- Leading the interdisciplinary NEPA team
- Work planning
- Budget and schedule tracking
- Documenting the process and keeping the administrative record
- Advising the executive committee with regard to work plan and schedule changes, budget needs, and other administrative and project management matters
- Day-to-day coordination with cooperating agencies
- Ensuring adequate communication and information exchange, both external and internal
- Producing and distributing progress reports, newsletters, and news
- Producing and submitting for publication required Federal Register notices
- Keeping the administrative record and maintaining project files
- Coordinating with US Fish and Wildlife Service for Section 7 consultation on endangered species and to satisfy Fish and Wildlife Coordination Act requirements
- Coordinating and assuring appropriate public involvement and participation in the project
- Coordinating contractual service procurements and efforts.

The management team will attempt to resolve conflicts and disputes that may arise over the management and administration of the project. In the event that the management team cannot reach agreement, the issue will be referred to the executive committee. The executive committee may direct that the conflict or dispute be resolved by mediation.

F. Interdisciplinary NEPA Team. The Review and Water Operations EIS will be prepared using an interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts. The interdisciplinary NEPA team will include a representative designated by the management team from each of the technical teams**.** The management team may, as necessary and appropriate as determined by the management team, add members to the interdisciplinary NEPA team. The management team will provide leadership for the interdisciplinary NEPA team. Interdisciplinary NEPA team meetings will be open public meetings**.**

The interdisciplinary NEPA team will be responsible for:

- Developing, evaluating, and screening water operation alternatives
- Coordinating and directing technical teams
- Providing information to support the public involvement program
- Drafting and assembling the Water Operations EIS
- Reviewing and responding to comments on the draft Water Operations EIS

The interdisciplinary NEPA team will attempt to resolve conflicts or disputes of a technical nature that arise with respect to the project. If the interdisciplinary NEPA team is unable to reach agreement in a timely fashion, the management committee will refer the dispute or conflict to the executive committee. The executive committee may direct that the dispute or conflict be resolved by mediation.

G. Technical teams. Technical teams in a variety of disciplines will support the interdisciplinary NEPA team and perform technical studies and evaluations. The lead agencies will appoint members to these technical teams as specified under Agency Contributions. The management team may, at its discretion, invite and add, from time to time, representatives of cooperating agencies and stakeholders to be technical team members. Each technical team will be responsible for its own organization. Each technical team will refer any dispute or conflicts arising within the technical team that cannot be resolved to the interdisciplinary NEPA team. Disputes or conflicts arising between technical teams will be addressed by the interdisciplinary NEPA team. The interdisciplinary NEPA team may direct that the dispute or conflict be resolved by mediation.

VI. GENERAL PROVISIONS OF UNDERSTANDING

A. Term. This Agreement will become effective on the last signature date. This Agreement shall remain in effect until terminated as provided herein or completion of a final Water Operations EIS, whichever is earlier. The signatories expect the final Water Operations EIS to be completed within five (5) years from the date of this

Agreement.

Any signatory party may terminate this Agreement by providing written notice to the other parties, effective 60 days following the date of delivery of such notice. Within ten (10) days after the termination or expiration of this Agreement, the management team will make accessible a full and complete copy of the then-current administrative record and project files to each signatory agency. The management team will provide a copy of the administrative record and project files to a signatory party within sixty (60) days after receiving a request for the record. The management team shall maintain the administrative record and project files for at least one year following the termination of this Agreement or until each of the signatory parties has received a copy of the administrative record and project files, whichever is later.

B. Decision Process. The signatories (lead agencies) are responsible for all decisions involving the Review and the Water Operations EIS and ESA-related processes and will make all final decisions on issues arising during the NEPA process. Decisions regarding the conduct of the Review and Water Operations EIS will be made by the signatories and must be unanimous.

C. No Delegation or Abrogation. Although this Agreement sets forth a cooperative process, all signatories to this Agreement recognize that they each have statutory and contractual responsibilities that cannot be delegated. This Agreement does not, and is not intended to, abrogate any of the signatory agencies' statutory duties. Nothing in this Agreement will be construed to amend or abridge the authority of any agency to carry out its legal responsibilities, mandates, or contractual obligations. The rights and obligations of the parties under this Agreement are contract rights and obligations only, and shall not be construed to modify in any way the statutory or regulatory duties of the parties.

D. Dispute Resolution. The signatories agree to use all reasonable efforts to resolve any disputes arising among them and to do so in a collaborative and timely manner. Disputes that cannot be resolved will be mediated. The team or committee responsible for resolution of a dispute or conflict will document the nature of any dispute and the resolution process used, and provide the documentation to the management team. The signatories, through the management team, will document in the administrative record the nature of any dispute and the resolution process used.

E. Modifying the Agreement. This Agreement may be modified by letter of agreement signed by the three decision makers or their designated representatives. Any modification shall be made in writing prior to implementing the change.

F. The Work Plan. The *Work Plan for the Upper Rio Grande Basin Water Operations Review* (Attachment A) defines the specific work items to be accomplished under this Agreement and provide associated schedule and budget information. The work plan shall be subject to periodic review, revision, and approval by the executive committee.

G. Correspondence. For coordination purposes, copies of all written correspondence from any signatory agency or EIS party to another person or entity pertaining to activities under this Agreement shall be sent by the originator to the originator's peers in the team, committee, or other relevant group to which the originator belongs.

H. Officials not to Benefit. No member of, or delegate to Congress, or resident Commissioner, shall receive any benefit that may arise from this Agreement.

VII. INVOLVEMENT OF COOPERATING AGENCIES

Agencies and governments with appropriate expertise or jurisdiction have been invited to participate in the NEPA process as cooperating agencies. The executive committee may, at any time during the course of the project, invite additional agencies to participate in the process as cooperating agencies. An agreement with each cooperating agency will be developed documenting specific expectations, roles, and responsibilities including such issues as preparation of analysis, schedules, and availability of pre-decisional information. Cooperating agency agreements must be signed by all of the signatories. A standard cooperating agency agreement is appended hereto as Appendix B.

VIII. PUBLIC INVOLVEMENT

The signatories, through the management team, will seek and encourage public involvement throughout the project. The management team will prepare a public involvement plan to present milestones to the public. The management team will submit for publication in the Federal Register a Notice of Intent to prepare an EIS, Notices of Availability of the draft and final Water Operations EIS, and Records of Decision. Notices will also be placed in the Federal Register on the availability of scoping information. Each lead agency, through the management team will be responsible for public involvement in the process. The responsibilities of the lead agencies will include conducting public scoping meetings, Water Operations EIS comment hearings, and other outreach activities.

IX. PRODUCTS

A. Water Operations EIS Documents. The Water Operations EIS Documents will be prepared in accordance with the National Environmental Policy Act and its implementing regulations and the Endangered Species Act and its implementing regulations:

- Notice of Intent to prepare an EIS
- Notice of availability of draft EIS
- Draft Environmental Impact Statement
- Notice of availability of final EIS
- Final Environmental Impact Statement
- Notice of availability of Record of Decision Record of Decision

The management team will be responsible for production and distribution of the Water Operations EIS documents.

B. ESA Compliance and Compliance with other federal law. The lead agencies shall establish a protocol for the integration with this Review of other federal and NMISC actions or decisions which relate to or may have an effect on the decisions and resources that are within the scope of this Review. This Protocol should include an explanation of the relationship between the project and other Environmental Assessments or Environmental Impact Statements, the manner in which the actions for which the project will be conducted will comply with the requirements of Sections 7 and 9 of the Endangered Species Act, and the manner in which decisions regarding the grant or denial of permits or other authorizations or discretionary actions will be incorporated within the project. The lead agencies will determine and document the timing and products for review by the United States Fish and Wildlife Service pursuant to the Endangered Species Act, and the organization structure for arrangements between the United States Fish and Wildlife Service and the three lead agencies.

C. Administrative Record. The management team will keep and maintain the administrative record for the EIS. The administrative record shall include all reports and other records establishing the factual basis and material to the development of the EIS and Records of Decision, such as correspondence among the signatories and EIS parties, including email; meeting notes; and public comments. Informal communications shall not be considered to establish the factual basis of the EIS and Records of Decision.

D. Records of Decision. Each of the signatories will publish a separate Record of Decision not less than 30 days following publication of the Final Water Operations EIS. Each agency's ROD will state its plan for future exercise of its authorities over water operations in the Upper Rio Grande Basin. While the intent of this Agreement is that the signatories will use all reasonable efforts to develop a preferred plan that will be adopted by all three signatories, this outcome is not assured.

X. AGENCY CONTRIBUTIONS

The BOR, COE, and NMISC will make funding and in-kind contributions during the term of the Agreement for purposes of completing the *Work Plan for the Upper Rio Grande Basin Water Operations Review* (Attachment A). The staffing commitments of the parties may be fulfilled using in-house staff or contractors.

The signatories will be responsible for funding their respective obligations identified in this Agreement and in Attachment A. If additional or unanticipated needs are identified in the course of the project, the signatories will review their respective budgets and mutually agree on the means of funding.

Commitments made under this Agreement are subject to approval and appropriations by state and federal legislative bodies. Nothing in this Agreement will require any of the signatories to exceed annual appropriations or personnel limits.

A. Bureau of Reclamation. BOR will:

1. Assign a project manager whose primary assignment is to manage the project process for BOR and participate as a member of the management team. The estimated resource commitment for the Reclamation project manager is 0.5 to 1.0 FTE per year.

2. Assign technical specialists as necessary to accomplish the Work Plan. The estimated resource commitment for BOR technical specialist participation is 0.3 FTE for each of 8 to 10 teams per year.

3. Assign staff and provide funding as necessary to accomplish the public involvement program. The estimated resource commitment for BOR public involvement program participation is 0.3 to 0.5 FTE.

4. Provide general support such as clerical support.

5. Provide written input for all documents and review materials within time frames set.

6. Review and comment on all draft documents and public information materials.

7. Provide appropriate existing data and analysis.

8. Provide funding for staffing, travel, and other participatory needs.

9. Provide work plans and statements of work for any necessary studies.

10. Provide draft copies for other agency review.

11. Continue to support development of the Upper Rio Grande Water Operations Model (URGWOM).

B. Corps of Engineers. COE will:

1. Assign a project manager whose primary assignment is to manage the project process for COE and participate as a member of the management team. The estimated resource commitment for the COE project manager is 0.5 to 1.0 FTE per year.

2. Assign technical specialists as necessary to accomplish the Work Plan. The

estimated resource commitment for COE technical specialist participation is 0.3 FTE for each of 8 to 10 teams per year.

3. Assign staff and provide funding as necessary to accomplish the public involvement program. The estimated resource commitment for COE public involvement program participation is 0.3 to 0.5 FTE.

4. Provide general support such as clerical support.

5. Provide written input for all documents and review materials within time frames set.

6. Review and comment on all draft documents and public information materials.

7. Provide appropriate existing data and analysis.

8. Provide funding for staffing, travel, and other participatory needs.

9. Provide work plans and statements of work for any necessary studies.

10. Provide draft copies for other agency review.

11. Continue to support development of the Upper Rio Grande Water Operations Model (URGWOM).

C. New Mexico Interstate Stream Commission. NMISC will:

1. Assign a project manager whose primary assignment is to manage the project process for NMISC and participate as a member of the management team. The estimated resource commitment for the NMISC project manager is 0.5 to 1.0 FTE per year.

2. Assign technical specialists as necessary to accomplish the Work Plan. The estimated resource commitment for NMISC technical specialist participation is 0.3 to 0.5 FTE for each of 6 to 10 teams per year.

3. Assign staff and provide funding as necessary to accomplish the public involvement program. The estimated resource commitment for NMISC public involvement program participation is 0.3 to 0.5 FTE.

4. Provide general support such as clerical support.

5. Provide written input for all documents and review materials within time frames set.

6. Review and comment on all draft documents and public information materials.

7. Provide appropriate existing data and analysis.

8. Provide funding for staffing, travel, and other participatory needs.

9. Provide work plans and statements of work for any necessary studies.

10. Provide draft copies for other agency review.

11. Increase support of development of the Upper Rio Grande Water Operations Model (URGWOM).

APPROVED:

New Mexico Interstate Stream Commission

____
Richard P. Cheney
Chairman

Date: ______________________________

U.S. Bureau of Reclamation

____
Charles A. Calhoun
Director, Upper Colorado Region

Date:_______________________________

U.S. Army Corps of Engineers

____
Peter T. Madsen
Brigadier General, U.S. Army
Division Engineer

APPENDIX A: Pertinent authorities and legal constraints on water operations in the Upper Rio Grande Basin

Appendix B: Charter of the Executive Committee

Appendix C: Charter of the Steering Committee

Attachment A: Work Plan

Attachment B: Standard Cooperating Agreement

APPENDIX A
WATER OPERATIONS AUTHORITIES

The signatories state that they have the following discretionary authorities over water operations in the upper Rio Grande basin, the exercise of which will be subject to consideration in the project.

A. Corps of Engineers Authorities: The COE operates reservoir facilities for flood and sediment control in the Upper Rio Grande Basin under existing authority of:

- PL 86-645 (1960) authorizes construction of Cochiti and Galisteo Dams and includes the operating criteria for Jemez Canyon, Abiquiu, Cochiti, and Galisteo Dams which includes:

1. " will be operated solely for flood control and sediment control

2. "the outflow from Cochiti Reservoir during each spring flood and thereafter will be at maximum rate of flow that can be carried at the time in the channel of the Rio Grande through the middle valley without causing flooding of areas protected by levees or unreasonable damage to channel protective works."

3. "that whenever the months of July, August, September, and October, there is more than two hundred twelve thousand acre-feet of storage available for regulation of summer floods and the inflow to Cochiti Reservoir (exclusive of that portion of the inflow derived from upstream flood -control storage) is less than one thousand five hundred cubic feet per second, no water will be withdrawn from storage in Cochiti Reservoir and the inflow derived from upstream flood-control storage will be retained in Cochiti Reservoir".

4. "Releases of water from Galisteo, reservoir and Jemez Canyon Reservoir during the months of July, August, September, and October, will be limited to the amounts necessary to provide adequate capacity for control of subsequent summer floods; and such releases when made in these months, or thereafter, will be at the maximum rate practicable under the conditions at the time.",

5. "all reservoirs will be evacuated completely on or before March 31 of each year..."

6. "that when estimates of anticipated streamflow made by appropriate agencies of the Federal Government indicate that the operation of reservoirs constructed as a part of the Middle Rio Grande Project may affect the benefits accruing to New Mexico or Colorado under provisions of the eighth unnumbered paragraph of Article VI of the Rio Grande Compact, releases from such reservoirs shall be regulated to produce a flow of ten thousand cubic feet per second at Albuquerque, or such greater or lesser rate as may be determined by the Chief of Engineers at the time to be maximum safe flow, whenever such operation shall be requested by the Rio Grande Compact Commissioner for New Mexico or the Commissioner for Colorado, or both, in writing prior to commencement of such operation."

7. "...nodeparture from the foregoing operation schedule will be made except with advice and consent of the Rio Grande Compact commission..."

8. "...whenever the Corps of Engineers determines that an emergency exists affecting the safety of major structure or endangering life and shall so advise the Rio

Grande Compact Commission in writing, these rules of operation may be suspended during the period of and to the extent required by such emergency."'

- PL 88-293 (1964) which authorizes a permanent pool in Cochiti Lake for recreation and fish and wildlife; the pool was established and maintained with San Juan -Chama Project water;
- PL 97-140 (1981) authorizes up to 200,000 acre-feet of contract storage of San Juan Chama project water in Abiquiu Reservoir with certain conditions;
- PL 100-522 (1988) authorizes storage of Rio Grande system water (up to 200,000 acre-feet) in Abiquiu Reservoir in the San Juan Chama storage space, if the San Juan Chama entities no longer require such storage; the storage of Rio Grande system water is subject to the provisions of the Rio Grande Compact; and
- Flood Control Act of 1944 (58 Stat. 890, 33 U.S.C. 709), Section 7, Flood Control Regulation for Platoro Reservoir, Conejos River, Colorado is the responsibility of the COE.

B. Bureau of Reclamation Authorities: The BOR operates reservoir and channel facilities in the Upper Rio Grande Basin under existing authority of:

- The Reclamation Act of 1902
- The Flood Control Acts of 1948 (PL 80-858) and 1950 authorize construction, operation, and maintenance of channel rectification works of the Middle Rio Grande Project, which includes the Low Flow Conveyance Channel.
- PL 87-483 (1962) authorizes the San Juan-Chama Project, which makes possible diversion of water from the upper tributaries of the San Juan River through the Continental Divide and into the Rio Grande drainage, not to exceed a maximum of 270,000 acre-feet in any one year, and limited to a total of 1,350,000 acre-feet in any consecutive ten-year period; the authorization allows water use to include municipal, irrigation, domestic, and industrial uses, and provide recreation and fish and wildlife benefits; Reclamation administers the contracts for San Juan-Chama Project water; Heron Reservoir is a facility of the San Juan-Chama Project and stores only water diverted from the San Juan Basin;
- PL 92-514 (1972) authorizes the Closed Basin project in Colorado to salvage groundwater that would otherwise be lost to evapotranspiration. The project helps the state of Colorado meet its required compact deliveries to New Mexico and to help all three states: Colorado, New Mexico and Texas meet their delivery requirements to the Republic of Mexico;
- PL 93-493 (1974) authorizes a recreation pool at Elephant Butte of 50,000 acre-feet; the state of New Mexico has contracted with the city of Albuquerque for San Juan -Chama project water to maintain the recreation pool since 1985;

C. New Mexico Interstate Stream Commission Authorities:

- Section 72-14-3, NMSA 1978 provides in part that NMISC "is authorized to … investigate water supply, to develop, to conserve, to protect and to do any and all other things necessary to protect, conserve and develop the waters and stream systems of this state, interstate or otherwise;… and to do all other things necessary to carry out the provisions of [Chapter 72, Article 14, NMSA 1978]."
- Section 72-14-20, NMSA 1978 provides in part that NMISC "authorized and empowered, to accept cooperation from the United States of America, its instrumentalities and agencies, in the construction, maintenance and operation ….. of any works authorized by this act, and the commission shall have full power to do any and all things necessary in order to avail itself of such aid, assistance and cooperation …."

D. Other Applicable Laws and Regulations

This Agreement, the Review, and the Water Operations EIS are subject to, and are intended to be consistent with, all applicable federal and state laws, regulations, agency policies, and interstate compacts including, but not limited to:

- The Rio Grande Compact of 1938, apportions the waters of the Rio Grande above Fort Quitman Texas among the states of Colorado, New Mexico, and Texas.
- The Rio Grande Convention of 1906 requires the United States to deliver 60,000 acre feet of water annually to Mexico. The National Environmental Policy Act of 1969, as amended (Public Law 91-910, 42 USC 4321-4347).
- Council on Environmental Quality (CEQ), Regulations for Implementing the Procedural Provisions of the NEPA (40 CFR Parts 1500-1508).
- U.S. Department of the Interior, Departmental Manual Part 516
- U.S. Department of the Interior, Bureau of Reclamation, National Environmental Policy Act Handbook, as revised (October 1990).
- The Endangered Species Act of 1973, as amended (P.L. 93-205; 87 Stat. 884, 16 U.S.C. 1531 et. seq.) Consultation and Regulatory Certainty Under Section 7 of the ESA, 16 U.S.C. Section 1536, federal agencies shall utilize their programs and authorities in furtherance of the purposes of the ESA and ensure that their actions are not likely to jeopardize listed species or adversely modify designated critical habitat of such species. Federal Cooperation with States Section 2(c)(2) of the ESA, 16 U.S.C. Section 1531(c)(2), states that "the policy of Congress is that federal agencies shall cooperate with state and local agencies to resolve water resource issues in concert with conservation of endangered species." Under Section 6 of the ESA, the Secretary of the Interior is directed to cooperate to the maximum extent practicable with the states in carrying out the program authorized by the ESA and to consult with the affected states before acquiring any land and water, or interest therein, for the purpose conserving listed species. Nothing

herein shall constitute an admission that any water related activities or new water related activities have caused or will cause adverse effects to endangered or threatened species or their habitats.

- Under the Fish and Wildlife Coordination Act, 16 U.S.C. ' 662, federal agencies must consult with the Service and with state wildlife agencies on the impacts to fish and wildlife resources of federal or federally licensed or permitted water projects.
- Water Pollution Prevention and Control Act (Clean Water Act). 33 U.S.C. Section 1251 et. seq.
- PL 100-633 which amends the National Wild and Scenic River Act of 1968 to include a portion of the Rio Chama the reach between El Vado, and Abiquiu Reservoirs as" wild and scenic " and designates another portion of the reach as a study reach for possible designation. The Corps, Reclamation, and the Bureau of Land Management (BLM) are jointly responsible for management of the reaches.
- Subject to applicable compacts and decrees, the State of New Mexico administers water rights.
- The State of New Mexico also has certain statutory authorities, including authority under Section 17-2-39, NMSA 1978, and responsibilities to protect and manage its fish and wildlife resources.
- Additional authorities:

National Parks, Monuments, Recreation Areas

Several laws established national monuments or recreation areas within the river basin. These units were established to provide for public outdoor recreation use and enjoyment and to preserve the scenic, scientific, and historic features of the area. (i.e., list the laws establishing Bandelier National Monument; Wild Rivers NRA; Ovielle Verde NRA; Quarai at Salinas Pueblo Missions National Monument; Abo at Salinas Pueblo Missions National Monument; Gran Quivira at Salinas Pueblo Missions National Monument; Valley of Fires NRA; Ft. Craig National Historic Site)

The following may also be applicable:

Antiquities Act of 1906 (16 U.S.C. 431 et seq.)
National Park Service Organic Act (16 U.S.C. 1-4, 22,43)
National Park Service General Authorities Act of 1970 (16 U.S.C. 1a-1)
Redwood National Park Act of 1978 (Public Law (P.L.) 95-250, 92-Stat. 163 as amended)
Energy Policy Act of 1992 (P.L. 102-486, Sec. 2402)

Environmental

Several laws and executive orders were designed to restore and protect the natural environment of the United States-air, water, land, and fish and wildlife.

Rivers and Harbors Act of 1899 (33 U.S.C. 401 et seq.)
Wilderness Act of 1964 (16 U.S.C. 1131 et seq.)
Wild and Scenic Rivers Act of 1968 (16 U.S.C. 1271 et seq.)
Clean Air Act (42 U.S.C. 7401 et seq.)
Executive Order 11991, Protection and Enhancement of Environmental Quality, 1977
Executive Order 11988, Floodplain Management, 1977
Executive Order 11990, Protection of Wetlands, 1977
Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations

Cultural Preservation

Several laws and executive orders were designed to protect and preserve historic and cultural resources under Federal control and/or in consultation with Indian Tribes.

Historic Sites, Buildings, and Antiquities Act (16 U.S.C. 461 et seq.)
Archaeological and Historic Preservation Act (16 U.S.C. 469 et seq.)
National Historic Preservation Act (16 U.S.C. 470 et seq.)
Executive Order 11593, Protection and Enhancement of the Cultural Environment, 1971
Archaeological Resources Protection Act of 1979 (16 U.S.C. 470 et seq.)
Executive Order 13007, Indian Sacred Sites, 1996

Tribal Laws and Regulations

Several laws and treaties established reservations and protect the rights of Native Americans to express, believe, and exercise traditional religious practices. Federal agencies are responsible for consulting with Indian Tribal Governments and traditional religious leaders to determine appropriate actions necessary for protecting and preserving Native American religious cultural rights and practices.

American Indian Religious Freedom Act of 1978
(42 U S.C. 1996)

Native American Graves Protection and

Repatriation Act of 1990 (25 U.S.C. 3001 et seq.)

Religious Freedom Restoration Act of 1993 (P.L. 13-141)

Laws or treaties establishing Indian Reservations within or adjacent to the study area

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APPENDIX B

CHARTER OF THE EXECUTIVE COMMITTEE FOR THE UPPER RIO GRANDE BASIN WATER OPERATIONS REVIEW AND WATER OPERATIONS ENVIRONMENTAL IMPACT STATEMENT

Membership: In accordance with the Memorandum of Agreement for the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (the Project) , the executive committee for the Project (executive committee) shall consist of the District Engineer, Albuquerque District, U.S. Army Corps of Engineers; the Area Manager, Albuquerque Area Office, Bureau of Reclamation; and the Interstate Stream Engineer for the New Mexico Interstate Stream Commission.

Role of the executive committee: The executive committee is responsible for accomplishing the review by allocating staff and funding resources from their respective agencies, providing guidance to staff, reviewing progress, and coordinating among signatory agencies.

The executive committee will review and approve changes to the Project work plan.

The executive committee shall establish a steering committee for the purpose of coordinating and exchanging information regarding the Project between the executive committee and representatives of cooperating agencies and key stakeholders. Representatives of all cooperating agencies, the Rio Grande Compact Commission, and key stakeholders that are identified by the executive committee will be invited to participate in the steering committee.

Decisions: Decisions of the executive committee shall be unanimous and will be approached in a constructive and collaborative manner. In the event that conflicts or disputes may arise that cannot be resolved within the committee itself, mediation of the dispute will be attempted. The executive committee will select and retain a mediator to provide conflict and dispute resolution assistance for the Project.

The executive committee will assist in resolving any disputes or conflicts referred by the management team or the interdisciplinary NEPA team.

Meetings: The executive committee shall meet at least three times a year, or more often as necessary.

The executive committee shall conduct steering committee meetings at least twice a year or more often if necessary.

APPENDIX C

CHARTER OF THE STEERING COMMITTEE FOR THE UPPER RIO GRANDE BASIN WATER OPERATIONS REVIEW

Membership: In accordance with the Memorandum of Agreement for the Upper Rio Grande Basin Water Operations Review and Water Operations Environmental Impact Statement (the Project), the steering committee for the project (steering committee) shall consist of the members of the executive committee (i.e. the District Engineer, Albuquerque District, U.S. Army Corps of Engineers; the Area Manager, Albuquerque Area Office, Bureau of Reclamation; and the Interstate Stream Engineer for the New Mexico Interstate Stream Commission), representatives from cooperating agencies, members of the Rio Grande Compact Commission, and key stakeholders invited by the executive committee.

Role of the Steering Committee: The purpose of the steering committee is coordination and exchange of information regarding the Project. The steering committee has no decision-making role.

Meetings: The executive committee will conduct steering committee meetings at least twice a year.

APPENDIX E
PUBLIC INVOLVEMENT REPORTS

Upper Rio Grande Basin
Water Operations Review

Upper Rio Grande Basin Water Operations Review and EIS Summary of Public Scoping Process

Prepared for:
U.S. Army Corps of Engineers
Albuquerque District
4101 Jefferson Plaza NE
CESPA-OD-W
Albuquerque, NM 87109-3435

February 15,2001

Contract # DACA47-97-D-0009

Delivery Order #3

SAIC®
Science Applications International Corporation
An Employee-Owned Company

Prepared by:
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Albuquerque, NM 87106

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Upper Rio Grande Basin Water Operations Review and EIS Summary of Public Scoping Process

1.0 Introduction

Public meetings were held to solicit input for preparation of an Environmental Impact Statement (EIS) and a comprehensive system-wide review of the water operations activities that are conducted under the existing authorities of the Joint Lead Agencies (JLA), the U.S. Army Corps of Engineers (COE), the Bureau of Reclamation (BOR), and the New Mexico Interstate Stream Commission (NMISC), in the Rio Grande basin above Fort Quitman, Texas. The project, called the Upper Rio Grande Basin Water Operations Review (Review) and EIS, will consider changes primarily of the storage and release of water at reservoirs in the basin.

To ensure compliance with the National Environmental Policy Act (NEPA), Council on Environmental Quality (CEQ) regulations (Title 40, Code of Federal Regulations [CFR], Parts 1500–1508) implementing NEPA, the COE NEPA regulations (33 CFR Part 230), BOR NEPA regulations (45 FR 47944 [7/17/80] as amended by 48 FR 17151 [4/21/83]), Department of Interior Manual 516 DM 1-7, and other applicable federal and state environmental legislation, the JLA will prepare a programmatic Water Operations EIS that documents the Review process and informs the public about the resource conditions and effects of any proposed actions on the environment. NEPA compliance includes public involvement activities such as scoping meetings. This activity, as well as additional public involvement activities, have been identified and scheduled in a Public Involvement Plan (September 30, 2000) developed for the Review.

2.0 Scoping Process

2.1 Preparation

In preparation for the scoping meetings, a market survey was conducted by interviewing community representatives and interested stakeholders. The goal of this survey was to assist the Project Managers in determining who the stakeholders are, how and where they get information, identifying their primary issues, and understanding their perceptions and knowledge of the JLA and their responsibilities. The Project Managers used this information to help develop the informational materials for the meetings and to select the methods for advertising the public meetings. The names and addresses of those interviewed were added to the mailing list.

The survey was conducted in five geographic areas of the basin and included representatives from nine stakeholder groups. It concluded that there is a very high level of interest about surface water issues. Based on survey results, documented in the "Stakeholder Opinion Research for the Upper Rio Grande Basin Water Operations Review EIS", sixty percent of the people interviewed stated that their primary source of community information is the newspaper. A large majority prefer to receive information about the Water Operations Review through direct mail and the newspaper.

The Project Managers sent a newsletter to almost 400 people in early June 2000 that summarized the purpose and goals of the Review and included a list of the times and locations of all public scoping meetings. The newsletter was also distributed at other meetings to those not on the mailing list. Public notices listing the scoping meetings were published in at least one local newspaper in advance of each meeting. (**See sample in Appendix C.**) The Project Managers and Executive Committee members also called or faxed key stakeholders to encourage their attendance at the scoping meeting in their area.

2.2 Scoping Meetings

All public scoping meetings were held from 6:00 p.m. to 9:00 p.m. and were informal, using an open house format. **Table 1** lists the meeting dates and locations. Attendees were encouraged to sign in and view displays by the technical teams that provided background information on the resources to be evaluated during the project. Displays included maps of the basin, which located areas of interest to their resource, graphs, lists of known issues, and other information. Available to everyone at the door were two project fact sheets, a basin map, and a newsletter. Handouts were also available from most of the technical teams at their display tables. **Appendix D** contains copies of the fact sheets and handouts. Media kits were provided to members of the press.

Table 1. Public Scoping Meeting Dates and Locations

Date	Location	Meeting Site
Wednesday, June 28	Alamosa, Colorado	Alamosa Elks Lodge 406 Hunt
Thursday, June 29,	Taos, New Mexico	Kachina Lodge 413 Paseo del Pueblo Norte
Wednesday, July 26	Española, New Mexico	Northern NM Community College 921 Paseo de Oñate
Wednesday, August 9	Chama, New Mexico	El Méson Lodge South Highway 84/64, 87520
Thursday, August 17	Albuquerque, New Mexico	Indian Pueblo Cultural Center 2401 12th Street NW
Wednesday, September 20	Santa Fe, New Mexico	Radisson Hotel 750 N. St. Francis Drive
Wednesday, September 27	El Paso, Texas	Hilton Hotel 2027 Airway Boulevard
Tuesday, October 17	Las Cruces, New Mexico	New Mexico State University Corbett Center
Wednesday, October 18	Socorro, New Mexico	New Mexico Institute of Mining and Technology Macey Center 801 Leroy Place

At approximately 6:30 p.m., a short slide presentation about the project was made by one of the Project Managers, followed by questions from the audience on the presentation. Specific questions on technical issues related to the resources to be studied were asked in the informal discussions at each display table after the slide presentation.

Questions and comments made by the public during and following the slide presentation were documented and are included in **Appendix A.** Each technical team representative was equipped with a flip chart so comments made during their discussions could be recorded. In addition, comment cards (**See Appendix B.**) were distributed at the registration table, which were collected at the meeting or mailed to a Project Manager later. These comments were categorized, grouped, and are summarized in the next section.

3.0 Meeting Results

3.1 Attendance

Attendance at the public scoping meetings ranged from one to forty people, counting only those in attendance who are not representatives of the JLA or cooperating agencies. Good discussion occurred at every meeting and some important issues were raised that will be considered by the technical teams during the development and analysis of the alternatives.

3.2 Comments

Comments are defined as statements or questions that are pertinent to the Review and EIS or that, while not directly within the scope of this project, are pertinent to water operations and management in the basin. Those outside the scope of this project will be documented and passed along to the appropriate agency for study under a different program.

All comments have been reviewed and categorized according to their content. Those questions and comments made during the discussion following the presentation at the meetings received responses at the meeting. They were also passed along to the appropriate technical team for consideration, along with those comments received on the cards. The comments from the public scoping meetings are available for review online at http://www.spa.usace.army.mil/urgwops/ or by contacting one of the three Project Managers.

There are twenty-two main categories, listed below. Additional categories or subcategories will be identified as needed throughout the project. The information following each category briefly describes the type of question or comment that was included under this category.

1. EIS and Scoping Process—how alternatives will be selected; how scoping and the meetings were conducted; in general, how the EIS will be developed.
2. Purpose and Need—goals for the project and EIS; who authorized the study; why the effort is being made.
3. Agencies and Authorities Involved/Project Scope—what agencies are involved; why some agencies are not involved; types of operations under consideration; definition and extent of authorities limiting the project.
4. Content, Methodology, Alternatives—definition of the system to be studied; models to be used in analyses; methodology and thoroughness of analysis.
5. Issues for Further Study but Outside Scope—suggested studies that cannot be included under this effort but that will be recorded for consideration under other programs.
6. Socioeconomics—effects of water operations and possible changes on local economies.
7. Environmental Justice—potential effects of changes in water operations on minority groups or small communities.
8. Land Use, Water Rights—impacts of land use along the river on river flows and water quality; potential effects of changing water operations on water rights.
9. Agriculture—potential effects of changing water operations on farmers and ranchers; need for evaluating the impacts of changing water operations on agriculture.
10. Riparian and Wetland Ecosystems—potential effects on bosque and other riparian or wetland areas; impacts on wildlife habitat; invasive plants of concern.
11. Cultural Resources—requirements for consultation; extent of survey and documentation.
12. Aquatic Systems—flows needed for fish; requirements for consideration of endangered species; effects on aquatic habitat from water operations decisions.
13. Water Quality—water quality standards and how they would be used; modeling.
14. Recreation—need to consider; importance of recreation businesses to the economy.
15. River Geomorphology—consider from historical perspective.
16. Sedimentation—sediment load, contamination, removal.
17. Hydrology and Hydraulics—effects of flows on groundwater; losses due to evaporation.

18. Water Operations/Structures—uses of dams; types of options to be considered in the alternatives; possible addition or removal of specific structures; why some structures not included in project; flood control.
19. Cumulative Impacts—effects of increasing population and water demands;
20. Relationship to Other Concurrent Projects—how this project relates to other water-related projects in the basin; effect of decisions from this project on other projects or agencies' work.
21. Public Involvement—public outreach opportunities; ways for the public to provide comments; meeting notification; comments on the meeting content and format.
22. Other Issues—not related to the Review and EIS.

Comments are grouped by main category in the graph below. Some comments were assigned to more than one category, so the total of the comments categorized below is greater than the total number of comments received.

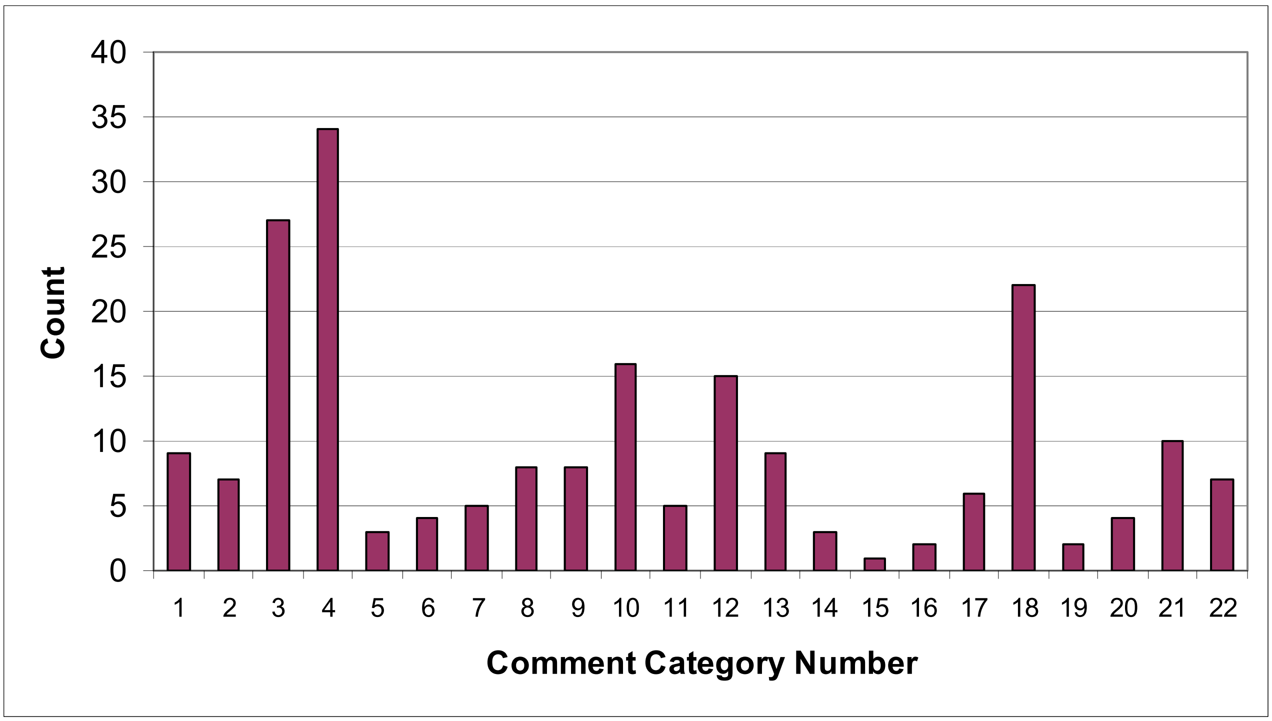

Figure 1. Comments Received During Scoping Process, Grouped by Category.

4.0 Upcoming Public Involvement Activities

It became clear during the scoping meetings that the stakeholders would like to discuss potential alternatives before they are selected and analyzed in the EIS. In response, the Project Managers committed to holding additional meetings to facilitate public discussion of alternatives. Other public outreach activities planned to be ongoing include the following.

- Press releases
- Newsletters
- Presentations to interested groups and organizations, as requested
- Presentations and briefings to tribal governments
- Workshops and tours
- Public meetings to discuss Review progress

- Public hearings on draft EIS

Comments and questions from the public can be submitted to the Project Managers through the web site, telephone, comment cards, or fax throughout the Review.

Appendix A:
Notes from Public Scoping Meetings

Comments from Upper Rio Grande Basin Water Operations Review Public Scoping Meeting; Alamosa, Colorado; Elks Lodge; June 28, 2000

Following is a summary of the questions, comments, and issues raised during the discussion that followed the formal presentation of the purpose and objectives of the Upper Rio Grande Basin Water Operations Review and EIS at the scoping meeting in Alamosa, Colorado. They are presented in the order they were discussed.

- What is the potential for taking water from Colorado for the Rio Grande silvery minnow?
- Will groundwater depletion by private organizations be addressed?
- Who authorized the study and the funding?
- How can the Compact be kept as a sideboard?
- Don't see the need for the study to include the Closed Basin.
- Is the EIS based on the way the system works now or on the proposed changes?
- How will the alternatives be ranked?
- Why is the EIS not evaluating economic impacts, only environmental impacts?
- How much will endangered species concerns drive the study? Isn't the bottom line the impacts to the Rio Grande silvery minnow?
- Will no private water operations be reviewed?
- What is the project really looking at? What do you hope to derive from Colorado? I heard that the agencies want to take Colorado water to augment flows for the Rio Grande silvery minnow.
- What would Rio Grande flows look like if they mimic natural flows? How could this be done and still maintain flood control?
- Would the project affect the groundwater at the Great Sand Dunes?
- Is the Rio Grande Reservoir involved?
- What are the lead agencies hoping to happen regarding the sediment load in the Rio Grande, much of which is contaminated? Do they plan to remove the sediment?
- Increasing water demands due to increasing population is a large issue. What does this project hope to find out about this issue? The agencies will hear more about this as they go downstream with scoping meetings.
- Is there a trend toward underground water storage?
- Will there be consideration of the creation of a conveyance channel to provide water to El Paso?
- How will the conflicting issues of conveyance efficiency, sustainable riparian systems, and flood control be addressed? How Elephant Butte is operated and how water gets there affects water users in the San Luis valley. Colorado is interested in protecting the Closed Basin Project and the Conejos River basin. It would be difficult to get the buy-in of Colorado people if there are negative impacts to San Luis valley water users.
- Hope to get a better understanding of the needs of endangered species from this process.
- What will the entire 5-year effort cost?
- To determine what the silvery minnow needs, the study must consider their habitat and the river system in 1850. How can the river system, in its current form, be compatible with the silvery minnow or the southwestern willow flycatcher? Endangered species needs cannot be

satisfied with the current river system. The silvery minnow habitat problem could be solved by getting rid of the dams on the river.

- If the lead agencies are bound by existing authorities that are clearly spelled out, is it possible to come up with anything different?
- What might result from this process?
- Will the teams look at average flows or extreme conditions such as drought?
- Is the Management Team dedicated full time to this project?

Comments from Upper Rio Grande Basin Water Operations Review Public Scoping Meeting; Taos, New Mexico; Kachina Lodge; June 29, 2000

Following is a summary of the questions, comments, and issues raised during the discussion that followed the formal presentation on the purpose and objectives of the Upper Rio Grande Basin Water Operations Review and EIS at the scoping meeting in Taos, New Mexico. They are presented in the order they were discussed.

- Will the project look at removing levees or doing non-structural features?
- What are the environmental justice issues?
- Environmental justice issue: In some areas, changes in flows could have a negative effect on water quality. If water quality decreases as a result of changing water operations, existing uses of that water, such as irrigation, could be affected.
- Environmental justice issue: The transfer of water rights could affect minority water users.
- (In response to information on the Socioeconomics Technical Team display) How is flood damage to houses an issue? Houses should not be built in the floodplain to begin with, so the socioeconomic impacts to these houses due to floods should not be considered.
- How do socioeconomic impacts relate to those developed for the silvery minnow recovery plan? How much would using the Low Flow Conveyance Channel (LFCC) affect Compact deliveries and how much can landowners use water from the LFCC?
- Benefits derived from mimicking natural flows include protection of native species, which provides a socioeconomic benefit.
- Will there be opportunities for public input during the definition of alternatives? Can the public obtain a copy of the alternatives?
- The sooner people know what alternatives will be considered in the EIS, the better prepared they can be to respond.
- How does the work product from this review relate to other federal projects?
- Will the capacity and purpose of the reservoirs be within the scope of this EIS?
- Reoperating reservoirs has a logical place in a study like this.
- What will be done with information that might require a change in authority?
- This process seems to be different in that it will provide more in-depth analysis of operations.
- Why are you not looking at Platoro and El Vado operations?
- It appears that three agencies are working together and some others are not. Was there an attempt to include other agencies?
- A major concern is that this effort will study water operations and how changes would affect resources, but it is losing the opportunity to look at the whole system because it is leaving out some of the reservoirs, which are key components.
- In response to the answer above, it was recommended that one alternative be used to look at operations outside the existing authorities. How could the system be changed if the agencies had free rein to change the system?
- Perhaps just the “plumbing” of the entire system could be studied, just the technical issues, without considering the legal issues. The model, URGWOM, could be run for the entire physical system.

- Recommend an alternative that has the Closed Basin Project release more water from May through September and less during the winter. This would help even out the summer low flows to benefit ecological and recreational values and meets one of the purposes of the Closed Basin Project.
- Was the MRGCD asked to be a lead agency?
- The Bureau of Reclamation does direct water releases at El Vado that are not controlled by the MRCGD.
- What about winter releases of San Juan-Chama water?
- Will the EIS study sensitive species in addition to endangered species, such as the Rio Grande cutthroat trout below Costilla Reservoir? For example, how has stopping the leakage from some of the dams affected cutthroat habitat?
- What is meant by the objective of providing a historical baseline?
- Will more archaeological survey work be done?
- Will the Cultural Resources Technical Team look at potential additions to the National Historic Register?
- Will the technical teams study biology and geomorphology from a historical perspective?
- Will the project look at tribal and state water quality standards?
- Will teams consider how flows and changes in operations would affect water quality? How the operations of dams affect water quality?
- Is there a model that can correlate water quantity to water quality?
- There is a potential for conflict between the needs of the Rio Grande silvery minnow critical habitat, the requirements for flows, and dam operations.
- To what degree will the operations in the San Acacia reach be included?
- Additional comments from technical team flip charts:
- Consider the effects of flows on aquifer recharge. How might changes in operations affect domestic wells and near shallow groundwater systems?
- How might changes in water operations affect wetlands?
- Don't forget rafting and kayaking recreational activities.

Comments from Upper Rio Grande Basin Water Operations Review Public Scoping Meeting; Española, New Mexico; Northern New Mexico Community College; July 26, 2000

Following is a summary of the questions, comments, and issues raised during the discussion that followed the formal presentation on the purpose and objectives of the Upper Rio Grande Basin Water Operations Review and EIS at the scoping meeting in Taos, New Mexico. They are presented in the order they were discussed.

- Is this a true NEPA process, without a predetermined Preferred Alternative? Who selects the Preferred Alternative? Will there be one Preferred Alternative or an array of options?
- People in the Española valley are suspicious that they will be called upon to provide water to the middle Rio Grande valley for the silvery minnow because the people in the upper watershed feel they have less political clout. Acequias above Otowi gage are concerned about getting bought out to satisfy the needs of the minnow.
- It might be useful to present information on URGWOPS to the regional water planning board.
- How will traditional cultural properties (TCP) in and near the river be addressed?

Comments from Upper Rio Grande Basin Water Operations Review Public Scoping Meeting; Chama, New Mexico; El Mesón Lodge; August 9, 2000

Following is a summary of the questions, comments, and issues raised during the discussion that followed the formal presentation on the purpose and objectives of the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (EIS) at the scoping meeting in Chama, New Mexico.

- Will this project affect the adjudication process?
- Does the project not deal with acequia and tribal issues?
- Tribes can do what ever they want to do.
- Most people in northern New Mexico cannot access the Internet. How can they learn about the project and keep up to date with its status and decisions? The lead agencies should have done a better job of getting the word out so more people from the community would attend this meeting and learn about the Water Operations Review and EIS.
- Agency representatives should talk to schools to teach the students the value of our resources. Bilingual information would also help to get the word out about the project. Other recommendations included setting up an exhibit at public functions like Chama Days and the Albuquerque Arts and Crafts Fair.
- People are tired of attending meetings and of not having the host agencies really hear their concerns.
- In response to a proposed change in the surface water area of Abiquiu Reservoir several years ago, a landowners' group formed and was effective in conveying their concerns to the Corps of Engineers. They were directly affected by the proposal and persistent in providing input to the Corps. People can get organized and make the agencies listen to them. In this project, it sounds like the agencies are asking for input at the beginning.
- El Vado and Abiquiu reservoirs are the "bread and butter" of northern New Mexico. This year these reservoirs are being drained. The local people would like to know when this will stop and why they were not notified that this would happen. People should realize that draining the storage water from the upper reservoirs has an immediate effect on the local groundwater. Maybe water operations are damaging the river right now.
- Why must the Rio Grande silvery minnow be protected? How will that affect the process?
- How strong is the regulatory authority of the agencies involved? There is a situation in the Chama area involving the use of pesticides that poisoned the surface water, yet the state departments of Agriculture, Game and Fish, and Environment would do nothing about it. Can the joint lead agencies control these state agencies so they will stop this problem?
- Is breaching dams, as some agencies are doing in the northwest U.S., an option being considered or is it possible to consider?
- One person heard that Texas wants to store water in Abiquiu Reservoir.
- It was recommended that a committee be formed in each community to provide input on the project. Who is on the Steering Committee?
- Can the general public make recommendations to the Steering Committee?
- Can the public recommend members to the Steering Committee?
- Are cultural concerns required to be addressed by law?
- The group expressed concerns that northern New Mexico rural communities do not have the political clout, population, and money to have their comments carry weight when the agencies select alternative water operations. They also wanted to make sure that the alternatives selected would be equitable and would not harm their part of the basin.
- Will there be a risk-benefit assessment?

Comments from Upper Rio Grande Basin Water Operations Review Public Scoping Meeting; Albuquerque, New Mexico, Indian Pueblo Cultural Center, August 17, 2000

Following is a summary of the questions, comments, and issues raised during the discussion that followed the formal presentation on the purpose and objectives of the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (EIS) at the scoping meeting in Albuquerque, New Mexico. Other comments made to technical team representatives after the formal presentation are listed at the end of these notes.

- Why was El Vado not included in the scope of this EIS?
- How will the Review address prior and paramount Indian water rights? This is unclear and partly incorrect in one of the water operations fact sheets.
- What are the effects on Indian water rights other than the prior and paramount water rights?
- Why are the facilities of irrigation districts and acequias not included for consideration of changes to their operations?
- In formulating the alternatives for the EIS, are you willing to look at changing water diversions and the effect of changing irrigation district diversions?
- How does an agency become a cooperating agency?
- It is unusual to have joint lead agencies as co-leads. What assurance do we have that the Records of Decision (ROD) that are issued will not conflict with each other, and that there will be decisions made to cooperatively implement the selected alternative? Why didn't you plan to issue only one ROD?
- The Middle Rio Grande Water Assembly works with federal, state, and local agencies and can incorporate public input related to all of those agencies. The Water Operations Review could use the Water Assembly's participants for getting public input, and work together for public outreach.
- In developing the alternatives, how do the lead agencies work outside their funding agreements and enabling acts for making changes to operations? Can you request changes to be made by Congress?
- Most of the public is not aware of what is an existing authority and what is outside the scope of this project.
- Will you be considering ways to reduce evaporative losses in the system?
- How can you do what is needed to regenerate cottonwoods in the Bosque through periodic flooding when parts of the system have new construction in the floodplain? The new buildings built in the floodplain in the Socorro area and the railroad bridge at San Marcial provide constraints to water operations changes that will be difficult to overcome.

Comments from the flip charts, recorded by technical team representatives:

- Can Regional Water Plans be posted on ISC web site once submitted to the ISC?
- Comments made to the Riparian and Wetland Ecosystems Technical Team
- Need to do salt cedar clearing.
- Bosque flooding–ecosystem health.
- Flow alternatives vs. ecosystem processes and land-water interface.
- Use creative engineering to divert flows throughout the levee system to enhance cottonwood regeneration.
- For NM Game and Fish—Rio Grande silvery minnow predators?
- Bovine encroachment in riparian areas

- How many days will overbank flooding last? 24 hours? 30-40 days?
- Get communities to appreciate how rare the Bosque really is.
- Trash will be increased and mobilized, including deceased animals, when flooding is released.

Comments from URGWOPS Public Scoping Meeting; Santa Fe, New Mexico; Radisson Hotel; September 20, 2000

Following is a summary of the questions, comments, and issues raised during the discussion that followed the formal presentation on the purpose and objectives of the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (EIS) at the scoping meeting in Santa Fe, New Mexico. They are presented in the order they were discussed. Other comments made to technical team representatives after the formal presentation are listed at the end of these notes.

- What is the time period for URGWOM calculations?
- How does URGWOM affect the State Engineer's decisions on other projects? How would the state use URGWOM to make decisions? For example, how would the projected diversions and timing of those diversions from the Rio Grande affect return flow credits?
- Who is using URGWOM?
- What is the relationship between the Bureau of Reclamation Draft EIS on the Low Flow Conveyance Channel and this Water Operations Review?
- When scoping began, the Rio Grande Project was not to be included in the Water Operations Review. Now that the federal district court has dismissed this case, will operations be addressed below Elephant Butte?
- Encourage agencies involved in the Review to look at old issues in the Rio Grande watershed, like the taking of land around Abiquiu Reservoir.
- The public scoping period is short, relative to the entire project timeline.
- Give some examples of improved flexibility and cooperation, and of increased efficiency that was referred to as a benefit of this Review.
- Does the Water Operations Review deal with San Juan water? Why isn't the City of Albuquerque involved?
- A major part of water loss in the system is due to evaporation. Is there a focus on technology to reduce losses?
- Why is El Vado Reservoir not highlighted?

From flip chart sheets:

- Preserve arroyo behind north section of dam.
- Very informative, learned a lot. Please do more of this.
- Newsletter to keep people informed would be a good idea.
- Give us water to raft on. We create jobs, tax base, and economic impact in some of the poorest counties in the nation. 8 cfs at the Colorado state line is unacceptable.
- Need a minimum pool established at Abiquiu. 75,000 acre-feet would be ideal!
- Remember the "intrinsic" value of the river—not just its 'instrumental" value. It has value in itself, not just what it can do for us.
- Great to have technical people to answer questions.

Comments from URGWOPS Public Scoping Meeting; El Paso, Texas; Airport Hilton Hotel; September 27, 2000

Following is a summary of the questions, comments, and issues raised during the discussion that followed the formal presentation on the purpose and objectives of the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (EIS) at the scoping meeting in El Paso, Texas. They are presented in the order they were discussed.

- Will the alternatives selected be plugged into URGWOM?
- How will the area below Elephant Butte benefit from this Review because water operations only address facilities above Elephant Butte.
- Will water quality be included in URGWOM?
- What is system efficiency?
- What is included in "regulatory compliance"?

Comments from Upper Rio Grande Basin Water Operations Review Public Scoping Meeting; Las Cruces, New Mexico; Corbett Center, New Mexico State University; October 17, 2000

Following is a summary of the questions, comments, and issues raised during the discussion that followed the formal presentation on the purpose and objectives of the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (EIS) at the scoping meeting in Las Cruces, New Mexico. They are presented in the order they were discussed.

- Will you be doing analysis for the river below Elephant Butte?
- Agriculture is apparently not represented in any of the technical teams.
- Agriculture should be addressed by a separate technical team, similar to recreation. Why not cover recreation under the Land Use Technical Team and designate a separate team for agriculture, which has a vested interest in water operations and the potential for important impacts to changing operations.
- A farmer or rancher can contribute a great deal to this project. It doesn't appear that ranching interests are represented either.
- It is a disservice to represent recreation and wildlife but not include specific representation of agricultural interests. Some of the dams in the basin were built for agriculture, not recreation or fish.
- Agriculture should be raised in importance by adding a technical team or developing a poster and other information on how it will be addressed.
- What baseline information will be covered for operation of the Rio Grande Project?
- How much of the Rio Grande Project is flood control? Is this a minor part of this project?
- Which litigation are you referring to? You are missing a tremendous opportunity to get baseline river information that is important to Las Cruces.
- The middle Rio Grande litigation seems to be as disruptive as the litigation below Elephant Butte, but limits have not been placed on evaluating water operations there.
- Will actions and alternatives be considered outside the river channel and the floodplain? For example, will salt cedar baseline information be collected? You should understand pre-dam vegetation to determine trends and changes in vegetation in the floodplain.
- Will you only evaluate current conditions or will you compare these conditions with historic data and project the effects of changes?

Comments from Upper Rio Grande Basin Water Operations Review Public Scoping Meeting; Socorro, New Mexico; Macey Center, New Mexico Institute of Mining and Technology; October 18, 2000

Following is a summary of the questions, comments, and issues raised during the discussion that followed the formal presentation on the purpose and objectives of the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (EIS) at the scoping meeting in Socorro, New Mexico. They are presented in the order they were discussed.

- Will URGWOM have scenarios that will analyze the impacts of removing some diversion dams?
- Does removal of structures "mess up" this study if they are removed after the study is complete?
- Is the City of Albuquerque's use of San Juan-Chama water part of this study?
- In the Socorro County Commission, we have discussed and supported construction of a dike on the west side, across from Bosque del Apache. The Commissioners have heard that this project has been cancelled, and they would like to state that with the construction of Elephant Butte, there has been significant damage to communities upstream along the river. Important cultural resources have been destroyed. The County Commissioners are concerned about what will happen to the remaining communities, like San Acacia and Socorro, if there is no protection from flooding.
- I am surprised that the USGS is not involved in this project.
- As a farmer, I am pessimistic about public involvement. Past experience with Fish and Wildlife Service (FWS) public meetings on wolves and threatened and endangered species has shown that FWS has the ultimate authority for the Endangered Species Act and can rule any way it wants. Public involvement justifies what FWS or other government agencies want to do. How do you intend to work around the FWS trying to keep the lead agencies from doing anything under the Water Operations Review?
- On flood control projects—the Socorro County Commissioners received a letter accepting their application for a flood control project. With three lead agencies in the Water Operations Review, it would be beneficial to the commissioners to request support from these lead agencies.
- Will you be addressing noxious weeds? Perennial pepperweed is a serious problem where there has been earthmoving. Please contact the Socorro Soil and Water Conservation District for more information.
- Can we get a complete list of all agencies involved in the Water Operations Review?
- The New Mexico Interstate Stream Commission has spent money supporting the development of regional water plans. Will these plans be incorporated into the Water Operations Review? A comprehensive plan cannot be developed without incorporating the regional water plans.
- The Socorro/Sierra Regional Water Planning group is directed by a steering committee that is composed of representatives of different water users in the community. We have quarterly meetings and coordinate closely with the NMISC. We hope that all input from the community in prioritizing how water is used becomes part of the Water Operations Review so that our issues and needs are established for this reach without duplicating efforts.

Water in New Mexico is too valuable to run down the river for a few minnows when the minnow is so easy to raise in other locations.

Appendix B:
Comment Card

UPPER RIO GRANDE BASIN WATER OPERATIONS EIS COMMENT CARD

As the Bureau of Reclamation, U.S. Army Corps of Engineers, and New Mexico Interstate Stream Commission, as joint lead agencies, undertake the preparation of an environmental impact statement (EIS) on water operations in the Rio Grande Basin, we invite you to participate. Your input in identifying important issues affecting water operations at the various facilities to be addressed in the EIS is important to the lead-agencies. Your input will assist us in the formulation of alternatives for exercising the discretionary authority of Reclamation and the other joint lead agencies. Please write your comments in the space provided below. Fold the card in half, tape the edges, and mail the completed card back to us. Comments, names, and addresses are generally made available for public review. Individuals wishing to have their name/address withheld from public disclosure, should check this box. ☐ Thank you.

NOTE: Please return written comments by:

Tape Here

fold here

fold here

Place Postage Here

FROM: ____________________

____

____

TO: MR. CHRIS GORBACH
TEAM LEADER
BUREAU OF RECLAMATION
505 MARQUETTE NW, SUITE 1313
ALBUQUERQUE, NEW MEXICO
87102-2162

Tape Here

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Appendix C
Sample Newspaper Advertisement

NOTICE OF PUBLIC SCOPING MEETINGS

For development of a draft Environmental Impact Statement(EIS) for

upper Rio Grande basin water operations

Meetings will be held to gather input from the public on potential issues and concerns that should be considered during the development of the Upper Rio Grande Basin Water Operations Review and EIS. The public meetings will include a presentation, an opportunity to discuss issues and ask questions of staff and managers, and an informal open house where technical teams will provide information on resources as well as receive comments. All meetings will begin at 6:00 p.m. and end at 9:00 p.m.

Alamosa, CO	**Wednesday, June 28**	**Alamosa Elks Lodge, 406 Hunt**
Taos, NM	**Thursday, June 29**	**Kachina Lodge, 413 Paseo del Pueblo Norte**
Espanola, NM	**Wednesday, July 26**	**No. NM Community College, 921 Paseo de Onate**
Chama, NM	**Wednesday August 9**	**El Meson Lodge, South Highway 84/64**
Albuquerque, NM	**Thursday, August 17**	**Indian Pueblo Cultural Center, 2401 12th NW**
Santa Fe, NM	**Wednesday, Sept. 20**	**Radisson Hotel, 750 N. St. Francis**
El Paso, TX	**Wednesday, Sept. 27**	**El Paso Airport Hilton, 2027 Airway Blvd.**
Las Cruces, NM	**Tuesday, October 17**	**New Mexico State University, Corbett Center**
Socorro, NM	**Wednesday, October 18**	**NM Institute of Mining and Tech., Macy Center**

Additional information is available online at http://www.spa.usace.army.mil/urgwops/ or by calling:

U.S. Army Corps of Engineers
Gail Stockton
505-342-3348
Fax: 505-342-3195

Bureau of Reclamation
Chris Gorbach/ Leann Towne
505-248-5379/5321
Fax: 505-248-5308

Interstate Stream Commission
Rhea Graham
505-841-9480
Fax: 505-841-9485

Upper Rio Grande Basin Water Operations Review and EIS

Summary of Draft Alternatives Meetings and Comments

Prepared for:

U.S. Army Corps of Engineers
Albuquerque District
4101 Jefferson Plaza NE
CESPA-OD-W
Albuquerque, NM 87109-3435

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SAIC®
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Prepared by:
2109 Air Park Road SE
Albuquerque, NM 87106

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Upper Rio Grande Basin Water Operations Review and EIS Summary of Public Meetings on Draft Alternatives

5.0 Introduction

At the public scoping meetings that were held to solicit input for the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (EIS) from June through October of 2000, participants expressed an interest in learning about the alternatives to be evaluated in the EIS before they were finalized. In response to this request from the public, the Joint Lead Agencies (JLA), the U.S. Army Corps of Engineers (COE), the Bureau of Reclamation (USBR), and the New Mexico Interstate Stream Commission (NMISC), held ten public meetings to discuss the possible components of the alternatives and the strategy for developing them into action alternatives planned to be in compliance with the National Environmental Policy Act (NEPA) of 1969, as amended [42 United States Code (USC) 4321 et seq.].

This summary of the public meetings on the draft alternatives describes the meeting arrangements, handouts, and comments received on the draft alternatives.

5.1 Alternatives Process

5.1.1 Preparation

To develop the alternatives, the JLA Project Managers worked with the technical teams to identify possible alternatives that might benefit specific resources and would be within the authorities of the lead agencies. They developed some visual aids in the form of a set of "playing cards" to explain the concept of varying water operations at different facilities within the Rio Grande system that were intended to help those who are not water managers understand the possible interrelationships between water operations and the scenarios that could be developed into action alternatives.

The alternatives were explained using a playing card analogy to describe current operations and proposed draft operations changes. The cards "we hold" were described as the current operations (No Action Fact Cards) at each of the facilities. The cards "we want to play" were described as the components of the draft alternatives, the possible changes to water operations at specific facilities or in particular reaches of the river. The possible changes must be evaluated beforehand so that we play the right card at the right time and know the outcome of that choice. Uncertainty was represented by two "wild" cards, one for variability of weather and runoff; the other, a "joker", to symbolize unplanned issues that may affect water management. Sets of the No Action Fact Cards were given to each participant at the public meetings. Sets of cards showing the possible components of the draft alternatives were printed and used at the meetings to demonstrate different combinations that could comprise alternatives to be evaluated. A copy of the cards is included in **Appendix D**.

Before the cards and the slide presentation for the public meetings were finalized, the concept was presented to the URGWOPS Steering Committee at their meeting on December 6, 2001. The committee members provided valuable feedback that the Project Managers used to refine the cards and their presentation. After all public meetings were completed, they were summarized to the Steering Committee at their June 27, 2002, meeting. Comments from the Steering Committee from the December 2001 meeting are included in the summarized and detailed comments (**Appendix B**) in this report. Comments from the Steering Committee at the June 2002 meeting were related mainly to technical team plans for future analyses of the alternatives. The committee expressed appreciation of the use of the cards to explain complex processes to the public. Details of the Steering Committee's questions and comments from the June 2002 meeting can be found in the meeting notes on the Upper Rio Grande Basin Water Operations Review and EIS web site at http://www.spa.usace.army.mil/urgwops/.

The Project Managers made the meeting room arrangements and had legal advertisements published in local newspapers in advance of the meetings. The meetings were also announced in the Upper Rio Grande Basin Water Operations Review newsletter mailed to the list of over 600 names in January 2002 and in the Public Notice that was faxed to each of the Southwest Region tribal officials.

Newspapers that published the advertisement shown in **Appendix C** include the Albuquerque Journal, Albuquerque Tribune, Placitas Northside Signpost, El Paso Times, Las Cruces News, Sierra County Sentinel, El Defensor Chieftain, Rio Grande Sun, Taos News, El Hispano News, and the Alamosa Valley Courier. Public service announcements were sent to KUNM-Albuquerque, KDCE-Española, and KFLH-Chama. Other public outreach included posting notices at various spots around town by the Abiquiu Project office staff and placing URGWOPS newsletters on a rack for free distribution in an Abiquiu store. Additional public outreach efforts involved invitations to groups such as the Abiquiu Advisory Committee, invited by Abiquiu Project Office, and the Española Planning and Zoning office staff who sent a notice via e-mail to the Jemez y Sangre Regional Water Planners.

5.2 Public Meetings

All public meetings on the draft alternatives were held from 7:00 p.m. to 8:30 p.m. **Table E-1.1** lists the meeting dates and locations. Attendees were encouraged to sign in and pick up handouts including a set of cards characterizing the No Action alternative, previously distributed newsletters, and the Purpose and Need statement for the project.

At approximately 7:00 p.m., a slide presentation was given by one of the Project Managers. The presentation included a brief overview of the project purpose and need, followed by an explanation of the concept of alternatives development for NEPA, and descriptions of the No Action alternative and the possible action alternatives, using the playing cards. The presentations were informal, and questions were encouraged.

Questions and comments made by the public during and following the slide presentation were documented. In addition, comment cards were distributed at the registration table, which were collected at the meeting or mailed to a Project Manager later. These comments were categorized, grouped, and are summarized in the next section. All comments from the flip charts and comment cards from each meeting, including the Steering Committee meeting on December 6, 2001 are listed in **Appendix A**, grouped by category**.** Some of the comments are included under more than one category.

Table E-1.1. Draft Alternatives Public Meeting Dates and Locations

Date	Location	Meeting Site
Tuesday, January 15	Las Cruces, New Mexico	NM Office of the State Engineer, District IV Office 1680 Hickory Loop, Suite J
Wednesday, January 16	El Paso, Texas	Chamizal National Memorial 800 S. San Marcial
Tuesday, February 5	Truth or Consequences, New Mexico	City Council Chambers 405 W. Third Street
Wednesday, February 6	Socorro, New Mexico	USBR Socorro Field Division 2401 State Road 1
Tuesday, March 19	Albuquerque, New Mexico	US Army Corps of Engineers 4101 Jefferson Plaza NE
Wednesday, March 20	Santa Fe, New Mexico	NM Department of Game and Fish 1 Wildlife Lane
Tuesday, April 16	Española, New Mexico	Rio Arriba County Complex 1122 Industrial Road
Wednesday, April 17	Abiquiu, New Mexico	Abiquiu Elementary School US Highway 84, Gate #21342
Tuesday, May 14	Alamosa, Colorado	USBR Alamosa Field Div., 10900 HWY 160 East
Wednesday, May 15	Pilar, NM	BLM Visitors Center State Highway 68

Meeting Results

5.3 Attendance

Attendance at the draft alternatives public meetings ranged from one to 55 people, counting only those in attendance who are not representatives of the JLA or cooperating agencies. Good discussion occurred at every meeting and some important issues were raised that will be considered by the technical teams during the development and analysis of the alternatives.

5.4 Comments

All comments have been reviewed and categorized according to their content. They were passed along to the appropriate technical team for consideration during final selection of the alternatives to be evaluated.

There are twenty-three main categories, listed below. The information following each category briefly describes the type of question or comment that was included under this category.

1. Agriculture—potential effects of changing water operations on farmers and ranchers; need for evaluating the impacts of changing water operations on agriculture, especially on acequias and the effect of increased flows on acequia diversions.

2. Authorities and Agencies Involved/Project Scope—what agencies are involved; why some agencies are not involved; how to become a cooperating agency; resources for project; state and federal laws; definition and extent of authorities limiting the project.
3. Content, Methodology, and Alternatives—definition of the system to be studied; models to be used in analyses; methodology and thoroughness of analysis; facilities to be included in impact analysis; how alternatives are to be selected.
4. Cultural Resources— extent of survey and documentation; types of information to be addressed; meaning of cultural resources.
5. EIS and Scoping Process— development of records of decision; in general; comment period for EIS.
6. Environmental Justice— evaluation of cultural properties/resources.
7. Hydrology and Hydraulics—channel capacity; lake levels; new gages needed in system.
8. Issues for Further Study but Outside Scope—suggested studies that cannot be included under this effort but that will be recorded for consideration under other programs.
9. Land Use, Water Rights—impacts of land use along the river on river flows and water quality; potential effects of changing water operations on water rights; rights to stored water now in system; possible changes to water rights.
10. Meeting Arrangements—comments on the meeting format and facilities.
11. Other Issues—not related to the Review and EIS.
12. Project Background—history of relevance to the project.
13. Public Involvement—topics to cover and ways to explain the alternatives to the public.
14. Recreation—less management is needed for recreation.
15. Riparian and Wetland Ecosystems—potential effects on bosque and other riparian or wetland areas; impacts on wildlife habitat; invasive plants of concern; managing riparian systems.
16. Sedimentation and Erosion—sediment loads; sediment in reservoirs; streambank erosion.
17. Socioeconomics—models to be used; evaluate other social factors; concern for local economics.
18. Threatened and Endangered Species—water delivery needed for fish; determine the requirements for endangered species, especially silvery minnow; effects on aquatic habitat from water operations decisions.
19. Water Delivery—use of San Juan-Chama water; maintenance of floodways; Compact obligations; water accounting.
20. Water Operations/Flows/Rivers—concerns over some of the flows proposed in alternatives under different channel capacities; impacts of changes in water operations on landowners
21. Water Operations/Reservoirs—uses of dams; evaporation losses; management of reservoirs and lake levels; storage of native water.
22. Water Operations/Structures—concerns over functioning of Low Flow Conveyance Channel.
23. Water Quality—mitigation of water quality impacts; meaning of water quality.

Comments shown in **Figure E-1.1** below are grouped by main category in the graph below. Some comments were assigned to more than one category, so the total of the comments categorized below is greater than the total number of comments received.

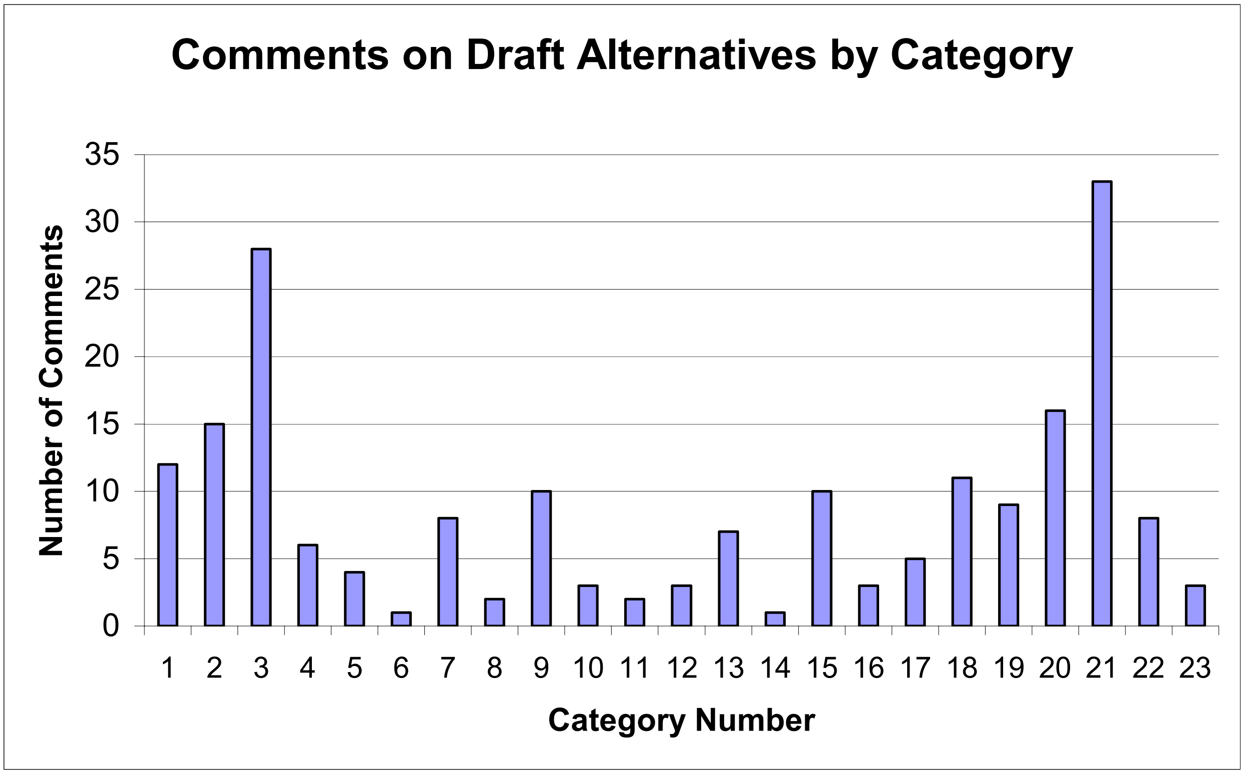

Figure E-1.1. Comments Received During Draft Alternatives Meetings, Grouped by Category

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Appendix A
Notes from Public Meetings on Draft Alternatives

Category:Agriculture

- Why isn't agriculture listed along with recreation and endangered species as a goal?
- One of the things we have to keep in mind when regulating the flows on the Rio Chama is in the event of a very wet winter, that the water is released so it does not go over 6,220 elevation. All the acequia users are so concerned about streambank erosion and damage to the diversion dams. Though we are landowners around the lake, when the lake rises, it floods extremely valuable riparian land, such as the Canones Creek. We are very fortunate to own this piece of land.
- Make water available for agrarian community lifestyle.
- Need to see words about farming, ranching, and agriculture in list of goals.
- Disappointing that ag, ranching not listed as priority.
- Can you look at operations that benefit acequias? Storage in Heron for example?
- Is there a graph for Rio Chama—hydrograph—is there one for the year—showing flows for critical months for agriculture?
- Ag priority must be addressed.
- Can consider storing native water in Abiquiu for irrigators in Rio Chama valley and water quality impacts—related to preservation of cultural resources.
- Danger to acequias from purchase of water rights by ABQ, other cities.
- Acequias and rural life around the acequias—affected by channel capacity are important and wiped out by high flows.

Category:Authorities and Agencies Involved/Project Scope

- Are the BIA and pueblos the same entity? How did entities get "invited" to be a cooperating entity?
- Under what statutory authority is this study being done?
- Have you asked other agencies to be cooperating agency (like county, other)?
- Who is the project proponent? What stimulated this whole thing?
- Who pays for the cost of the Review and EIS?
- What is a Cooperating Agency? How do you become one? What are the benefits of being one? Are you on mailing list?
- Do you get some "say" that others do not have?
- Definition of cooperating agency and how to become one?
- Familiar with public law. that created Abiquiu Dam? Why SJ-C water/intent?
- Benefits of cooperating agencies? Have voice/input others don't?
- Resources—technical or financial required of a cooperating agency? Cost to acequia?

- Can the acequias become formal cooperators?
- New Mexico manages water flowing through it.
- How does this play into state and federal laws and agencies?

Category:Content, Methodology, and Alternatives

- How come up with initial combinations of alternatives?
- Definition of mitigation?
- Who makes the decision about the draft alternatives?
- Management does not equal "lay" language.
- Are you trying to keep overbank flooding from occurring?
- How does URGWOPS affect north of NM line?
- Plans for river through valley (San Luis)?
- Is reach 13-14 the entire BOR Rio Grande project?
- Is ABQ use of SJ-C water part of No Action?
- NEPA process for drawdown of Caballo?
- Which LFCC configuration will be used to evaluate alternatives?
- Consider effects of ABQ wastewater and Isleta cultural values.
- Are some cards trumping other cards?
- Have you established a baseline?
- In summer, talk of ladder at San Acacia dam—part of this Review?

Category:Cultural Resources

- Treaty of Guadalupe Hidalgo takes precedence over ESA. Cultural values are endangered.
- What do you mean by cultural resources?
- Will there be a balance with cultural resources?
- Aside from Native American resources, what are considered cultural resources?
- Can consider storing native water in Abiquiu for irrigators in Rio Chama valley and water quality impacts—related to preservation of cultural resources.
- What does "cultural resources" include? Does it include acequias?

Category:EIS and Scoping Process

- Is it possible to have 1 ROD for all agencies?
- Consider longer public comment period for DEIS.
- Review half-way through? Can't understand why more people didn't show up.
- Does this EIS become (a) manual for managing water?

Category:Environmental Justice

- Will there be an environmental justice evaluation of cultural properties/resources?

Category:Hydrology and Hydraulics

- For evaporation, lose less water if get it down the river faster?
- Alternative—consider channel and levee maintenance to allow improved channel capacity for normal flows in reaches
- What is safe channel capacity? How arrived at?
- Also safe channel capacity.
- Discussion of storage and safe channel capacity is important.
- Use Cochiti recreation pool to maintain hydrograph—for drought reserve.
- Need to educate public on water levels in system, lake levels historically.

Category:Issues for Further Study but Outside Scope

- Another thing that should be very important to look at is erosion control projects around upstream of the lake—for example, the Canones Creek. If the Corps of Engineers would construct cement planks so the river can't erode any deeper, this would improve the quality of the water you are conveying downstream, and (this) would help the sediment build-up.
- One more thing is the trash. The Corps of Engineers should look at the illegal dumping here in Canones, just above the Canones Creek. (Every) time this arroyo or wash flash-floods, there (are) tons of trash moved with the water downstream to the lake. Again, this would do wonders for the quality of water downstream.
- Companion study for water rights ownership?

Category:Land Use, Water Rights

- Need more discussions on providing acequias water from Abiquiu storage.
- Who has rights to the native water to be stored in Abiquiu?
- Is transfer of water rights a legislative mandate?
- Ghost Ranch water belongs to RCAA.
- RCAA use (storage) of Abiquiu water so irrigation earlier; also, pueblos.
- Concerned about separation of water rights from the land. It's permanent.
- Do other property owners have storage rights (e.g. like Ghost Ranch)?
- Is damage being done to property owners? Is the high concentration of water table—high releases—keep land wet—create wet areas—is this a takings?
- Are there any other entities with storage rights in Abiquiu (apart from City of Albuquerque)?

Category:Meeting Arrangements

- Please have another meeting place.

Category:Other Issues

- In closing, we are very concerned about the storage water at the lake because we do not get any benefit from the lake. We lost some of our land the government condemned. All this happened to (serve) the needs of someone else, such as the acequias and the City of Albuquerque. The Corps of Engineers also sides more with these entities than the landowners, the ranchers around the lake. For instance, the office manager at Abiquiu can't see a cow grazing by the water, because he calls me on the phone to get them out; yet they cannot do anything about the trash problem on Highway 96, where all the sightseers (throw) trash as they walk down to the lake. We own all this property.

- How (do you) avoid being drawn into lawsuits on water use and delivery?

Category:Project Background

- Congressional Report on the Upper Rio Grande—1936? 1930s Congressional Report on Upper Rio Grande—good
- information for history.
- Treaty of Guadalupe Hidalgo can't be changed—ag, timber, grazing rights.
- Difficult to understand what you're doing.

Category:Recreation

- Like to see less management for recreation—water is precious and should not be used.

Category:Riparian and Wetland Ecosystems

- 500 cfs—is this the new concept/design—when LFCC moved to west side of valley? Reason—no constructed channel through
- SWWF habitat—new design with no diversion (counter to RGCC recs to meet delivery).
- Provide funding to get rid of trash trees (elm, Russian olive), conservation, drink water, harm ditches, fields, bosque.
- Look at controlling noxious weeds (saltcedar) that damage riparian areas and use water.
- How flush saltcedar from riparian areas to re-establish native vegetation?
- Have you considered management of forest land along Rio Grande? Water content of P-J, susceptible to fire; increased
- number of trees.
- Requirement for fish and wildlife habitat on reservoirs?
- Is saltcedar eradication part of the project?
- One of the things we have to keep in mind when regulating the flows on the Rio Chama is in the event of a very wet winter, that the water is released so it does not go over 6,220 elevation. All the acequia users are so concerned about streambank erosion and damage to the diversion dams. Though we are landowners around the lake, when the lake rises, it floods extremely valuable riparian land, such as the Canones Creek. We are very fortunate to own this piece of land.
- Management should be done to keep river, bosque, [and] fish healthy. Municipal and industrial use is secondary.

Category:Sedimentation and Erosion

- Degradation/Clean Water Act. 1,800 cfs below Abiquiu to much; 1,200 cfs too much. Sand sedimentation "extreme" at Chamita (historical acequia).
- Is accumulation of silt in reservoirs a significant factor?
- Another thing that should be very important to look at is erosion control projects around upstream of the lake—for example, the Canones Creek. If the Corps of Engineers would construct cement planks so the river can't erode any deeper, this would improve the quality of the water you are conveying downstream, and (this) would help the sediment build-up.

Category:Socioeconomics

- Use economics model?
- Can economic analysis look at micro effects on local areas and not just look at macro level?
- Can other social factors be examined as well? Treaties protect agriculture, grazing, and timber rights.
- Did the original legislation for San Juan-Chama compact provide for economic development?

Category:Threatened and Endangered Species

- BOR staff dug up minnows 7 feet down in river bed.
- If SJ-C water can be used for T&E species, shouldn't it be used in the San Juan watershed (its native watershed) for that purpose? Why use non-native water to support T&E?
- What's the water delivery for the minnow and flycatcher?
- Will the study look at what happens when T&E species demands [to] use up water and leave reservoirs dry?
- Does BOR consider SJ-C water as supply for silvery minnow?
- Treaty of Guadalupe Hidalgo takes precedance over ESA. Cultural values are endangered.
- Will ESA and T&E species have precedence over other concerns?
- What happens if new T&E species is added and must be addressed?
- How did minnow survive all those years when river was dry (late summer)?
- Need honesty in this process regarding T&E. River has been dry in past at times.

Category:Water Delivery

- LFCC - How does Bosque del Apache get water if no diversion?
- There is someone who knows at any given time [make-up of water]—just needs to be put in model or format that someone can find out.
- Is there someplace to go (e.g. Internet) [to learn] what the make-up of water is that is moving through the river?
- Does New Mexico have control of the amount of water delivered to Texas - Compact obligations? Like Colorado?
- Colorado River compact allocates 11% water to New Mexico (Regulatory Congressional report—1930s—SJ-C).
- When would ABQ begin using their SJ-C water?
- Is there active plan to maintain floodway above SM if no diversion to LFCC?—would cause problems for NM to meet compact obligations. Otherwise at cross-purposes.
- Management should be done to keep river, bosque, [and] fish healthy. Municipal and industrial use is secondary.

Category:Water Operations/Flows/Rivers

- Is there a graph for Rio Chama—hydrograph—is there one for the year—showing flows for critical months for agriculture?

- What's the impact of channel capacity > 1,200 cfs on acequias on Rio Chama?
- Can an alternative look at channel capacity < 1,200 cfs below Abiquiu?
- Include Rio Chama in Rio Grande.
- Can you look at what elevation would flood the 285 highway?
- Flows above 1,200 cfs damage ditches, cause erosion, destabilize banks.
- High flows (> 1,200) damage banks.
- Don't recall ever seeing 2,500 cfs.
- San Juan-Chama water does not benefit locals—burdens the valley with high flows.
- High channel capacity, even 1,200 cfs, is too much.
- Acequias and rural life around the acequias—affected by channel capacity are important and wiped out by high flows.
- Land ownership within banks of Rio Chama—need to evaluate compensation of these landowners from impacts of water operations.
- Taking into account SJ-C diversions at ABQ?
- Don't recall ever seeing 2,500 cfs.
- Even 1,200 cfs is too much from Abiquiu. (RCAA) comment since 1992. Corps has recorded damages at 1,800 cfs.
- Is channel capacity at 1,200-2,500 for both Chama and Rio Grande?
- There's no way to control flow in Rio Grande.

Category: Water Operations/Reservoirs

- Was no provision for easements at Abiquiu. Rationale: 1) Cultural preservation 2) Reparations for SJ-C trespass.
- Can you look at operations that benefit acequias? Storage in Heron for example?
- Can consider storing native water in Abiquiu for irrigators in Rio Chama valley and water quality impacts—related to preservation of cultural resources.
- Concern: Wakes on Abiquiu—but some disagree.
- Is there a significant difference in evaporation rate at reservoirs high up (El Vado and Heron) vs. those lower down
- (Elephant Butte and Cochiti) that make them preferable for storage?
- What would state's position [be] if agency applied for permit above 6,220 feet in Abiquiu?
- Increase/make storage in Cochiti.
- Use Cochiti recreation pool to maintain hydrograph—for drought reserve.
- Concern for low lake levels at Abiquiu.
- Change Cochiti authorization to add flexibility to manage in droughts.
- Do all dams have a minimum pool required?

- How would 200k native storage in Abiquiu affect homes?
- Would ABQ have to evacuate storage for conservation storage [n Abiquiu]?
- How will future demands in ABQ affect Abiquiu drawdown?
- Is there space between 6,220 and 6,250 feet in Abiquiu for storage authorized now? Easements not currently in place.
- Marinas in Elephant Butte that must be moved is an issue.
- Will the study look at what happens when T&E species demands [to] use up water and leave reservoirs dry?
- What will happen when water drains from Abiquiu? No native water now?
- One of the things we have to keep in mind when regulating the flows on the Rio Chama is in the event of a very wet winter, that the water is released so it does not go over 6,220 elevation. All the acequia users are so concerned about streambank erosion and damage to the diversion dams. Though we are landowners around the lake, when the lake rises, it floods extremely valuable riparian land, such as the Canones Creek. We are very fortunate to own this piece of land.
- Easement level of ABQ water at Abiquiu?
- Will current SJ-C issues in Heron, Abiquiu, and Cochiti be included? Will there be additional alternatives added to consider different operations?
- If go to 6,220 feet at Abiquiu, it floods highway.
- Suggest make storage available for Rio Chama Acequia Association.
- Is additional space to be acquired at Abiquiu?

Category: Water Operations/Structures

- LFCC - considering seasonal timing of diversions?
- How will this system (LFCC) work?
- Is there active plan to maintain floodway above SM if no diversion to LFCC?—would cause problems for NM to meet compact obligations. Otherwise at cross-purposes.
- LFCC - not going to stop drainage into it.
- 500 cfs—is this the new concept/design—when LFCC moved to west side of valley? Reason—no constructed channel through
- SWWF habitat—new design with no diversion (counter to RGCC recs to meet delivery).
- LFCC-BOR function as a drain—will this be part of alternatives? Used at a reduced rate as drain only, no diversion.
- No LFCC diversion is now the preferred alt.
- Lack of LFCC with lack of maintenance channel will hurt NM—impacts must be considered—add to alternative.

Category: Water Quality

- Degradation/Clean Water Act. 1,800 cfs below Abiquiu to much; 1,200 cfs too much. Sand sedimentation "extreme" at Chamita (historical acequia).
- Can you elaborate on water quality? What do you mean by water quality?

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Appendix B
Notes from Steering Committee Meeting on Draft Alternatives
December 6, 2001

Category: Agriculture

- Define problems and needs of resource: 1) What does silvery minnow need that it is not getting now? 2) What are our problems in meeting the compact? 3) What are needs of irrigators? 4) What is the timing of those needs? Then we can examine the flexibility in the system as far as timing of releases.

Category: Authorities and Agencies Involved/Project Scope

- Eliminate differences in individual agencies, operational rules, and regulations.
- Consider legal and institutional constraints prior to operations changes (i.e. treaties, compacts, decrees, statutes, constitutional issues). It may be that present operations are best alternative.

Category: Content, Methodology, and Alternatives

- Is all data available, or do we need more?
- If the above recommendation cannot be followed, then the No Action alternative should at least include extreme ranges of initial storage levels as a Wild Card phenomena.
- Despite the litigation, alternative storage levels in Elephant Butte should be modified and considered in the EIS.
- I tend to agree with the No Action flexibilities presented. With more information, I may alter my viewpoint.
- Structure models and data (info) so as to achieve the practical application by responsible planners.
- Express that a combination of alternatives could be an alternative.
- Modification of existing facilities needs to be taken into account (i.e. San Marcial Bridge and channel changes). It should be addressed.
- Include El Vado as a (Wild) Card even through it's no change. Identify flexibility at El Vado as Wild Card.
- Add a number of mid-stream flow gages, plus gages of all significant diversions and inflows. Return flows to facilitate system management. Make resulting data available on a real-time basis.
- Develop a matrix of combinations and permutations of alternatives.
- Overlapping circles indicating conflict versus agreement are fine, but they need to take discharge elevation into account.
- How will timing dimesion be incorporated into alternatives analysis?
- Add El Vado.

Category: Hydrology and Hydraulics

- URGWOM will be much improved in the future with gages at all river outflow/inflow points.

Category: Land Use, Water Rights

- Consider all tribal, constitutional, legal, and natural restraints or use prior to evalution of water supply.

Category: Meeting Arrangements

- (Have) facilitator to help communicate.
- You asked for more alternatives and ideas, but you shut all of them down and there were reasons certainly; but what will happen if the public gets that response? It was a fairly negative experience.

Category: Public Involvement

- Education on this important water issue is timely and imperative.
- For public presentations, take example issues (e.g., minimum flow for minnow, ABQ diversion of SJC, etc.) and show how flexibilities and scenarios could affect those issues: mitigate, enhance, injure, etc.
- Suggest narrative write-up of analysis of single-objective posters (to provide a means of sharing what the managers learned here).
- Explain authorities really well.
- When you deal with lay people, you need to clearly explain what this is going to accomplish.
- Express implications of "what if" scenarios.
- Remember to emphasize: 1) Rio Grande compact obligations, 2) Mexican treaty obligations.
- For clarity, rename CB scenario as 60K instead of 600K.
- Simplification of "rule-training" and "compact" requirements in URGWOM planning model needs to be transparent (i.e., well-described and defended).

Category: Riparian and Wetland Ecosystems

- What are the consumptive demands and future projections?

Category:Socioeconomics

- Human dimension considerations -- what are priorities?

Category: Threatened and Endangered Species

- Define problems and needs of resource: 1) What does silvery minnow need that it is not getting now? 2) What are our problems in meeting the compact? 3) What are needs of irrigators? 4) What is the timing of those needs? Then we can examine the flexibility in the system as far as timing of releases.

Category: Water Delivery

- Define problems and needs of resource: 1) What does silvery minnow need that it is not getting now? 2) What are our problems in meeting the compact? 3) What are needs of irrigators? 4) What is the timing of those needs? Then we can examine the flexibility in the system as far as timing of releases.

Category: Water Operations/Reservoirs

- Store native water in Cochiti.
- Reassess ownership of reservoir evaporation losses.
- Multi-level outlet works.

- Managing Jemez Dam as wet reservoir and/or to provide sediment to Middle Rio Grande -- flexibility was identified in consultation with tribes. Take a closer look at any potential benefits that this dam can provide to the overall integrated operations plan.
- Examine constraints to increasing storage of native water in any/all upstream reservoirs.
- Hold water higher as long as possible; release water from Elephant Butte instead of storing it, or charge evapotranspiration losses to Elephant Butte Irrigation District, not Middle Rio Grande Conservancy District --> regarding compact charge.
- Cover reservoirs.
- Maybe problems have to do with timing of releases.
- Identification of additional up-basin storage capacity.

Category:Water Quality

- Authorization to operate pools to cycle reservoirs to mitigate water quality concerns.

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Appendix C
Sample Newspaper Advertisement

NOTICE OF PUBLIC INFORMATION MEETINGS

For development of a draft Environmental Impact Statement (EIS) for

Upper Rio Grande Basin Water Operations

Meetings will be held to describe draft alternatives and to get feedback from the public before the alternatives are finalized. The public meetings will begin with a presentation that describes the current operations, which is the draft "No Action Alternative." The draft alternatives are being developed in an iterative process, which is why input from the public is so important. The public will be provided an opportunity to comment on the draft alternatives identified, using an informal open house. All meetings will begin at 7:00 p.m. and end at 8:30 p.m.

Las Cruces, NM	Tuesday, January 15	NM OSE, Dist. IV Office, 1680 Hickory Loop, Suite J
El Paso, TX	Wednesday, January 16	Chamizal National Memorial, 800 S. San Marcial
T or C, NM	Tuesday, February 5	City Council Chambers, 405 W. Third Street
Socorro, NM	Wednesday, February 6	USBR Socorro Field Division, 2401 State Road 1
Albuquerque, NM	Tuesday, March 19	US Army Corps of Engineers , 4101 Jefferson Pl. NE
Santa Fe, NM	Wednesday, March 20	NM Dept. of Game & Fish, 1 Wildlife Ln.
Espanola, NM	Tuesday, April 16	Rio Arriba County Complex, 1122 Industrial Rd.
Abiquiu, NM	Wednesday, April 17	Abiquiu Elem. School, US Highway 84, Gate #21342
Alamosa, CO	Tuesday, May 14	USBR Alamosa Field Div., 10900 HWY 160 E.
Pilar, NM	Wednesday, May 15	BLM Visitors Center, HWY 68

Additional information is available online at **http://www.spa.usace.army.mil/urgwops/** or by calling:

U.S. Army Corps of Engineers	*Bureau of Reclamation*	*Interstate Stream Commission*
Gail Stockton	*Steve Kolk*	*Rhea Graham*
505-342-3348	*505-248-5383*	*505-841-9494, ext. 128*
Fax: 505-342-3195	*Fax: 505-248-5308*	*Fax: 505-841-9484*
gail.r.Stockton@spa02.usace.army.mil	*skolk@uc.usbr.gov*	*rgraham@ose.state.nm.us*

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APPENDIX F
ADMINISTRATIVE RECORD AND RECORD OF DECISION
(WILL BE INCLUDED IN FINAL EIS)

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Appendix F—Administrative Record

An administrative record database is being maintained by the Corps for this EIS. As part of this, documents have been scanned to be made available for future use by those interested in the upper Rio Grande Basin.

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APPENDIX G
RELEVANT LAWS AND REGULATIONS

Table of Contents

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1.0 APPLICABLE LAWS AND REGULATIONS

The Water Operations Review and EIS are subject to, and intended to be consistent with, all applicable federal and state laws, regulations, agency policies, and interstate compacts including but not limited to those listed below.

1.1 Federal Statutes and Policy Documents

1.1.1 Natural Resources

Statues and Executive Orders were designed to restore and protect the natural environment of the United States—air, water, land, and fish and wildlife—include:

- P.L. 100-633, which amends the National Wild and Scenic Rivers Act of 1968 to include a portion of the Rio Chama, the reach between El Vado and Abiquiu Reservoirs, as "wild and scenic" and designates another portion of the reach as a study reach for possible designation.
- The Endangered Species Act of 1973 (ESA), as amended P.L. 93-205; 87 Stat. 884, 16 U.S.C. 460 et seq.) including Consultation and Regulatory Certainty Under Section 7 of the ESA, 16 U.S.C. Section 1536.
- Under the Fish and Wildlife Coordination Act, 16 U.S.C. 661, (2005), federal agencies must consult with the Fish and Wildlife Service and with state wildlife agencies on the impacts to fish and wildlife resources of federal or federally licensed or permitted water projects.

Other Federal statutes and policy documents addressing natural resources that may apply include:

- Rivers and Harbors Appropriation Act of 1899, 33 U.S.C. 401 et seq.
- Wilderness Act of 1964, 16 U.S.C. 1131 et seq.
- Clean Air Act , 42 U.S.C. 7401 et seq. (1970).
- National Environmental Policy Act of 1969, as amended (Public Law [P.L.] 91-910, 42 U.S.C. 4321-4347).
- Clean Water Act, 33 U.S.C. 1251 et seq. (2005).
- Executive Order 11991, Protection and Enhancement of Environmental Quality, May 24, 1977, 42 FR 26967.
- Executive Order 11988, Floodplain Management, May 24, 1977, 42 FR 26951 (see EO12148, amending, in part, EO 11988).
- Executive Order 11990, Protection of Wetlands, May 24, 1977, 42 FR 26961, amended by EO 12608, September 9, 1987.

1.1.2 Social and Cultural Resources

Some of the Federal laws and policies established to provide for public outdoor recreation use and enjoyment, and to preserve scenic, scientific, and historic features that are applicable to this Review and EIS are listed below.

- Historic Sites, Buildings and Antiquities Act, 16 U.S.C. 461 et seq. (2005).
- Archaeological and Historic Preservation Act, 16 U.S.C. 469 et seq. (2005).
- National Historic Preservation Act, 16 U.S.C. 470 et seq. (2005).
- Archaeological Resources Protection Act of 1979, 16 U.S.C. 470 aa et seq. (2005)

- Antiquities Act of 1906, 16 U.S.C. 431 et seq. (2005)
- National Park Service Organic Act, 16 U.S.C. 14-4, 22, 43. (2005)
- General Authorities Act of 1970, 16 U.S.C. 1a-1. (2005)
- Executive Order 11593, Protection and Enhancement of the Cultural Environment, May 13, 1971, 42 FR 26967
- Executive Order 13007, Indian Sacred Sites, 1996, May 24, 1996, 61 FR 26771.
- Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, February 11, 1994, 59 FR 7629 (See EO12948 amending, in part, EO 12898, January 30, 1995, 60 FR 6381).

1.2 State and Local Statutes, Regulations, and Policies

1.2.1 Natural Resources

- Air Quality Control Act, §§ 74-2-1 to -17 NMSA 1978 (1967).
- Air Quality (Statewide), Chapter 20.2.72 NMAC 2005.
- Albuquerque/Bernalillo County Air Quality Control Board, Chapter 20.11.3 NMAC 2005.
- Water Quality Act, §§ 74-6-1 to -17 NMSA 1978 (1967).
- Environmental Compliance Act, §§ 74-7-1 to -8 NMSA 1978 (1983).
- Endangered Plants, § 75-6-1 NMSA 1978 (2004).
- Endangered Plant Species List and Collection Permits, Part 19.21.2 NMAC 2005.
- Removal, Capture or Destruction of Endangered Species, Part 19.33.2 NMAC 2005.

1.2.2 Social and Cultural Preservation Acts

- Historic District and Landmark Act, §§ 3-22-1 to –5 NMSA 1978 (1983).
- Habitat Protection Act, §§17-6-1 to –11 NMSA 1978 (1973).
- Cultural Properties Act, §§18-6-1 to –23 NMSA 1978 (1969).
- Preservation and Maintenance of Registered Cultural Properties, Part 4.10.4 NMAC 2005.
- Review of Proposed State Undertakings that May Affect Registered Cultural Properties, Part 4.10.7 NMAC 2005.
- New Mexico Prehistoric and Historic Sites Preservation Act, §§18-8-1 to –8 NMSA 1978(1989).
- Implementation of the Prehistoric and Historic Sites Preservation Act, Part 4.10.12 NMAC 2005.
- Religious Freedom Restoration Act, §§ 28-22-1 to –5 NMSA 1978 (2000).

1.3 Tribal Laws, Regulations and Policies

Many Federal laws and executive orders were designed to protect and preserve historic and cultural resources under Federal control in consultation with Native American Tribes. Some of the ones most applicable to this Review and EIS are listed below.

- American Indian Religious Freedom Act of 1978, 42 U.S.C. 1996a.
- Native American Graves Protection and Repatriation Act of 1990, 25 U.S.C. 3001 et seq.
- Religious Freedom Restoration Act of 1993, 42 U.S.C. 2000 cc et seq.

- Executive Order 13007, Indian Sacred Sites, May 24, 1996, 61 FR 26771.
- Secretarial Orders 3175, 3206, and 3215 on Indian Trust Assets.
- Applicable Tribal laws implementing federal laws.
- Laws or treaties establishing Indian Reservation within or adjacent to the project area.

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APPENDIX H
RIVER MECHANICS AND GEOMORPHOLOGY

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1.0 SUMMARY OF METHODS AND ASSUMPTIONS FOR URGWOPS SEDIMENT-CONTINUITY ANALYSIS

A sediment-continuity analysis was performed to assess the effects of the various URGWOPS EIS alternatives on the sediment-transport characteristics and vertical stability of the Rio Grande between Cochiti Dam and Elephant Butte Reservoir (Geomorphic Reaches 10 and 12 through14). For purposes of this analysis, the geomorphic reaches were further subdivided to provide additional resolution that would better reflect the variability in bed material and geomorphic characteristics, and the presence of vertical controls along the reach (**Table H-1.1**). The approximately 1.3-mile long reach between the Angostura Diversion Dam and the confluence with the Jemez River was neglected in the analysis because the reach is very short compared to the other subreaches. The continuity analysis was performed by estimating the annual bed-material transport capacity of each subreach under the various alternatives and comparing that capacity with the bed-material supply from the upstream river and local tributaries within the subreach. Where the transport capacity of a particular subreach exceeds the supply, degradation (or channel downcutting) is indicated, and where the supply exceeds the capacity, aggradation is indicated. It should be kept in mind, however, that significant amounts of downcutting or aggradation could also lead to lateral instability.

The bed-material transport capacity of each subreach was estimated using reach-averaged hydraulic conditions and a representative bed-material gradation with an appropriate bed-material transport equation. Reach-averaged hydraulics were determined using output from the FLO-2D modeling that was performed by the Hydraulics Team, and the representative bed- material sizes were determined by developing a composite gradation from the available bed-material data that have been collected during the last decade within each reach. The median (D_{50}), D_{16} (size for which 16 percent, by weight, is finer) and D_{84} particle sizes for each subreach are summarized in **Table H-1.2**.

Except for Subreaches 10a and 10b (Cochiti Dam to Bernalillo), the median bed-material size through the study reach is sand. Based on similarity between the conditions for which the relationship was developed and comparison of computed results with available bed-material transport measurements at gages along the reach, the Yang (Sand) relationship (Yang, 1973) was selected for use in Subreaches 12 through 14. The median size in the representative bed-material gradation curve for Subreach 10a, which was developed from BOR range-line data, is about 13.5 mm, with about 30 percent in the sand-size range. In Subreach 10b, the representative gradation curve has a median size of 1.2 mm, and about 42 percent is gravel. The Yang (Sand) equation appeared to significantly overestimate bed-material transport capacities in these subreaches. After evaluating other relationships, it was determined that the Wilcock and Crowe (2003) relationship, that was developed for conditions where the bed material consists of a bimodal mixture of sand and gravel, provided results that were closer to observed trends, and this equation was, therefore, used for both Subreaches 10a and 10b.

The selected equations were used to develop rating curves for each subreach that represent a single-valued relationship between the bed-material transport capacity and discharge over the range of flows that occur in the URGWOM-developed flow record (**Figure H-1.1**). This procedure results in a simplified model that does not consider differential transport rates of grain sizes with changes in discharge and/or grain-size distribution. Local variations in grain size, such as at arroyo mouths or at changes in channel planform and slope, are also generalized into the representative bed-material gradation curves for each of the sediment-continuity subreaches. The model, therefore, calculates general trends, not specific changes within a subreach.

The bed-material supply to Subreach 10a (Cochiti Dam to Angostura Diversion Dam) was assumed to be negligible because essentially all of the sediment from upstream reaches is trapped in Cochiti Reservoir. Thirty-four (34) tributaries were identified along the study reach that deliver sediment to the Rio Grande downstream from Cochiti Reservoir (**Table H-1.3)**. Review of recent aerial photography indicated that three of the tributaries (Agua Sarca Arroyo, San Lorenzo Arroyo, and Coyote Arroyo) are intercepted by lateral drains or canals, and contribute insignificant bed-material volumes to the Rio Grande. Additionally, a detention basin located near the mouth of Montoyas Arroyo traps the majority of bed material before it reaches the Rio Grande. The bed-material supply from each of the remaining tributaries was computed using a variety of methods, depending on the amount of available information. For Galisteo Creek, the bed-material contribution below Galisteo Dam was developed from information in RTI (1994), which relied on trap efficiency estimates based on reservoir resurveys in 1972 and 1983. Until recently, Jemez Canyon Dam was operated to trap sediment; thus, the bed-material supply from the Jemez River to the Rio Grande was assumed to be negligible for purposes of evaluating historic conditions. Sediment loads from the North Diversion Channel (NDC) were obtained from a study performed by U.S. Army Corps of Engineers Waterways Experiment Station (WES) to evaluate sedimentation conditions in the NDC (Copeland, 1995). The basic sediment supply information used by Copeland (1995) was developed from a study of the arroyos draining to the NDC that was performed by Mussetter and Harvey (1994). Annual bed-material loads for nine tributaries in the reach between San Acacia and Elephant Butte Reservoir with drainage areas ranging from 3 to 47 mi^2 (Arroyo Sevilleta, Arroyo de Alamillo, Arroyo del la Parida, Arroyo de los Pinos, Arroyo de Tio Bartolo, Arroyo de la Presilla, Arroyo del Tajo, Arroyo de las Canas, and San Pedro Arroyo) were based on estimates developed by MEI (2003) for the New Mexico Interstate Stream Commission (NMISC). Results from MEI (2003) were also used to develop a relationship between unit annual bed-material load and drainage area, and this relationship was used to estimate bed-material loads from six arroyos located upstream from the Rio Puerco (Borrego Arroyo, Tonque Arroyo, Las Huertas Arroyo, Arroyo de la Baranca, Pajarito Arroyo and Comanche Arroyo) and seven additional arroyos located downstream from the Rio Puerco (Palo Duro Canyon, Los Alamos Arroyo, Bernardo Arroyo, Canada Ancha, Canoncito Colorado, Arroyo Rosa de Castillo and Arroyo del Veranito) that were not considered in MEI (2003). Because the unit yield relationship predicted unrealistically low bed-material loads from Abo Arroyo, Calabacillas Arroyo and the South Diversion Channel, annual bed-material loads were estimated by assuming a unit bed-material supply of 0.1 ac-ft/mi^2, which is generally consistent with the range of unit yields from the tributaries for which information is available. The procedure used to estimate the supply from the Rio Puerco and Rio Salado are discussed in the next paragraph.

The sediment-continuity analysis was validated, to the extent possible, by estimating aggradation/degradation trends using the computed average annual transport capacity within each subreach based on the measured flows during the post-Cochiti period of record (**Figure H-1.2** and **Figure H-1.3**), and comparing those trends with observed bed changes during that period (**Figure 1-4**). The results shown in **Figure H-1.2** through **Figure H-1.4** include adjustments to the Rio Puerco and Rio Salado sediment load that were made to improve agreement between the computed and observed conditions. The Rio Puerco was historically one of the major contributors of sediment to Rio Grande because of incision that occurred in the 1800s. Over the past few decades, however, the channel in the downstream reach of the Rio Puerco has narrowed and significant riparian vegetation has established on the valley floor, which likely significantly limits the bed-material supply to the mainstem, compared to the earlier periods for which data are available. As a result, the supply from the Rio Puerco was adjusted so that the total supply to Subreach 14a is in balance with the subreach capacity. Although specific data are not available to validate the estimate, the 25 ac-ft per year estimate that was obtained using this procedure is believed to be reasonable. The bed-material supply from the Rio Salado (48.6 ac-ft per year) was estimated using a similar procedure so that the estimated amount of aggradation between the Rio Salado and San Acacia Diversion Dam matched the slight aggradational trend that is indicated by BOR rangeline data collected between 1992 and 2002. In general, the estimated trends are very consistent with the observed trends along the reach (**Figure H-1.4**). Average annual aggradation/degradation estimates shown in **Figure H-1.4** represent the change in sediment volume spread uniformly over each subreach, along with the change in mean bed elevation over the past few decades from available BOR rangeline data. (Note that the actual time period of the comparison varies with location along the reach due to limitations in the available data.) In evaluating this information, it is important to note that the actual changes will not occur uniformly throughout the reach or across the channel at any given location, nor will they continue progressively for a long period of time because the bed material, channel geometry and gradient will adjust to compensate for imbalances between the sediment supply and transport capacity. In spite of this limitation, the plot provides a basis for comparing the general trends that occurred during the period with the results from the sediment-continuity analysis.

Although the agreement between the measured and computed trends in **Figure H-1.4** is reasonable, the figure does not reflect recent changes to the operations of Jemez Canyon Dam. Recent changes in dam operations result in a significant reduction in sediment trap efficiency compared to historic conditions, resulting in a significant increase in bed-material supply to the Rio Grande. These changes were also evaluated with the existing conditions hydrology because the EIS alternatives will incorporate the increased sediment supply. The effects of the increase were evaluated by assuming an annual contribution of 50 ac-ft per year from the Jemez, based on information provided by the Corps of Engineers (USACE). Currently, the bed material in the Rio Grande is relatively coarse between the confluence with the Jemez River and about Bernalillo (Subreach 10b, **Table H-1.2**), and the supply from the Jemez River is believed to be primarily sand. With the resupply of sediment from the Jemez River, it is likely the Rio Grande will initially adjust to the higher load by fining of the bed material, with a commensurate increase in transport capacity. For purposes of the analysis, it was assumed that the transport capacity of Subreach 10b will increase to accommodate the larger tributary loading, with no net change in bed elevation. The results of this “recent conditions” analysis are summarized in **Figure H-1.5 and Figure H-1.6**. These results appear to be consistent with observed recent trends in the reaches downstream from the Jemez River, and the 50 ac-ft per year supply was incorporated into the sediment-transport analysis for purposes of evaluating the EIS Alternatives.

The relative effects of the EIS No-Action and Action Alternatives were evaluated by integrating bed-material transport capacity rating curves (**Figure H-1.1**) over the 40-year flow records that were developed from the URGWOM planning model to obtain annual bed-material loads, and comparing those loads with tributary and upstream sediment supplies developed using the above-described procedures. The results of these analyses are summarized in **Figure H-1.7 through Figure H-1.9**. For purposes of evaluating the magnitude of the differences, the volumes shown in **Figure H-1.8** were converted into an average annual change in bed elevation by assuming the volume is spread uniformly over the entire reach based on the subreach length and average width. The resulting average annual bed elevation changes under the No-Action Alternative are as follows:

Subreach	Change in Bed Elevation (ft)[1]
10a	-0.05
10b	-0.17
12a	0.14
12b	0.01
13	0.00
14a	0.04
14b	0.12
14c	-0.08
14d	0.08

[1]Positive indicates aggradation, negative indicates degradation

Except for the subreaches below the San Acacia Diversion Dam, the computed change in bed elevation for the Action Alternatives is nearly identical to the values for the No-Action Alternative. In the Subreach 14c, aggradation of between 0.01 and 0.03 feet was computed for the Action Alternatives. In Subreach 14d, the computed change in bed elevation was negligible under Alternatives D-3, I-2, and I-3, and degradation of 0.01 feet was computed under Alternatives B-3, E-3, and I-1. **It should be noted that the indicated changes in bed elevation should be viewed only in a relative sense because the changes will likely not occur uniformly in time or space over the reach, nor will they continue indefinitely as the channel geometry, gradient and bed material adjust toward a state of equilibrium with the upstream supply.**

The results in **Figure H-1.7** through **Figure H-1.9** generally indicate that the differences in transport capacities for the Action and No-Action Alternatives are relatively small for the portion of the study reach upstream from San Acacia Diversion Dam, with Alternative I-1 being very similar to the No-Action alternative, and slightly reduced transport capacities (generally less than about 5 percent) for the other alternatives. The differences downstream from San Acacia are significant due to the operations of the Low Flow Conveyance Channel (LFCC) under the Action Alternatives. The results shown in **Figure H-1.7** through **Figure H-1.9** were obtained by assuming that the bed material supplied to the diversion will split into the LFCC and downstream river (Subreach 14c) in direct proportion to the amount of water that is delivered to each channel. The actual effect of the diversion on bed-material supply to the downstream river will, of course, depend on the specific operating procedures that are used, including procedures for limiting bed-material load into the LFCC and periodically flushing sediment to the downstream river. As a result, a sensitivity analysis was performed to evaluate the potential effects of these operations, which, to the knowledge of the River Morphology Team, have not yet been defined. The sensitivity analysis consisted of two additional scenarios that assumed the diversion would be operated in a manner that would result in 25 and 75 percent of the upstream sediment loads, respectively, being supplied to the downstream river. The results of the sensitivity analysis are summarized in **Figure H-1.10 and Figure H-1.11.** These figures indicate that, under the assumption that was used in the initial analysis, the downstream reach would be degradational under the No-Action Alternative and slightly aggradational under all of the Action Alternatives. This occurs because the amount of flow in the Subreach 14c is significantly reduced under the Action Alternatives, which causes a commensurate decrease in transport capacity. If 75 percent of the upstream supply is delivered to the downstream reach, the aggradation tendency becomes relatively significant. With the reduced (25 percent) supply, the downstream reach would be approximately in balance for all of the alternatives except Alternatives I-1 and I-2, because the flow volumes delivered to the subreach under these two alternatives is similar to the No-Action Alternative.

Table H-1.1 Summary of subreaches used for the sediment-continuity analysis

Subreach	Subreach Length (ft)	Limits
10a	117,574	Cochiti Dam to Angostura Diversion Dam
10b	23,886	Jemez River confluence to Bernalillo (HWY 44)
12a	19,650	Bernalillo (HWY 44) to Rio Rancho Sewage Treatment Plant Outfall
12b	161,850	Rio Rancho Sewage Treatment Plant Outfall to Isleta Diversion Dam
13	220,389	Isleta Diversion Dam to Rio Puerco confluence
14a	43,011	Rio Puerco confluence to Rio Salado confluence
14b	13,179	Rio Salado confluence to San Acacia Diversion Dam
14c	182,570	San Acacia Diversion Dam to RM 78
14d	71,172	RM 78 to San Marcial

Table H-1.2 Summary of representative bed- material gradation parameters for each of the sediment-continuity subreaches.

Subreach	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)
10a	0.47	13.50	60.22
10b	0.30	1.21	23.49
12a	0.36	1.04	6.73
12b	0.27	0.49	1.07
13	0.16	0.32	0.51
14a and 14b	0.17	0.33	0.60
14c	0.15	0.30	0.56
14d	0.11	0.20	0.37

Table H-1.3 Summary of tributaries included in the sediment-continuity analysis, and the average annual bed-material contribution from each of the tributaries

Table 3. Summary of tributaries included in the sediment-continuity analysis, and the average annual bed-material contribution from each of the tributaries.

Tributary Name	Drainage Area (mi^2)	Average Annual Sediment Volume (ac-ft)	Unit Volume (ac-ft/mi^2)	Source
Galisteo Creek*	43.0	4.6	0.11	RTI Main Report (1994)
Borrego Arroyo	75.0	1.7	0.02	Unit Yield Analysis
Tonque Arroyo	163.0	3.6	0.02	Unit Yield Analysis
Las Huertas Arroyo	29.2	0.6	0.02	Unit Yield Analysis
Jemez River	1034.0	0.0	0.00	Assume all bed matl load trapped under historic Jemez operations
Agua Sarca Arroyo	5.7	0.0	0.00	Intercepted by Albuquerque Main Canal u/s of Bernalillo
Arroyo de la Baranca	9.6	0.2	0.02	Unit Yield Analysis
Calabacillas Arroyo	100.8	10.1	0.10	Assume 0.10 ac-ft/mi2
Montoyas Arroyo	61.0	0.0	0.00	Intercepted by Detention Basin
N Diversion Chnl	102.0	8.3	0.08	Copeland, et.al. (1995)
S. Diversion Chnl	133.0	13.3	0.10	Assume 0.10 ac-ft/mi2
Pajarito Arroyo	0.9	0.4	0.47	Unit Yield Analysis
Comanche Arroyo	15.0	0.3	0.02	Unit Yield Analysis
Abo Arroyo	290.0	29.0	0.10	Unit Yield Analysis
Rio Puerco	7188.8	25.0	0.00	Back-computed for equilibrium in SR6a
Palo Duro Canyon	63.5	1.4	0.02	Unit Yield Analysis
Los Alamos Arroyo	58.8	1.3	0.02	Unit Yield Analysis
Bernardo Arroyo	1.8	0.4	0.19	Unit Yield Analysis
Canada Ancha	4.5	0.2	0.03	Unit Yield Analysis
Canoncito Colorado	1.8	0.4	0.20	Unit Yield Analysis
Rio Salado	1419.3	48.6	0.03	Based on USBR measured bed elevation change in SR6b
Arroyo Rosa de Castillo	5.5	0.1	0.03	Unit Yield Analysis
San Lorenzo Arroyo	30.5	0.0	0.00	Intercepted by San Lorenzo Settling Basin
Arroyo Sevilleta	2.6	0.3	0.13	MEI Tributary Study, MEI (2003)
Arroyo de Alamillo	3.2	0.2	0.06	MEI Tributary Study, MEI (2003)
Arroyo del Veranito	5.8	0.1	0.03	Unit Yield Analysis
Arroyo del la Parida	42.1	0.6	0.01	MEI Tributary Study, MEI (2003)
Coyote Arroyo	3.2	0.0	0.00	Intercepted by Eastside Drain
Arroyo de los Pinos	12.1	0.2	0.02	MEI Tributary Study, MEI (2003)
Arroyo de Tio Bartolo	2.6	0.2	0.09	MEI Tributary Study, MEI (2003)
Arroyo de la Presilla	15.5	0.3	0.02	MEI Tributary Study, MEI (2003)
Arroyo del Tajo	9.0	0.2	0.02	MEI Tributary Study, MEI (2003)
Arroyo de las Canas	26.3	0.4	0.01	MEI Tributary Study, MEI (2003)
San Pedro Arroyo	47.3	0.6	0.01	MEI Tributary Study, MEI (2003)

* Below dam

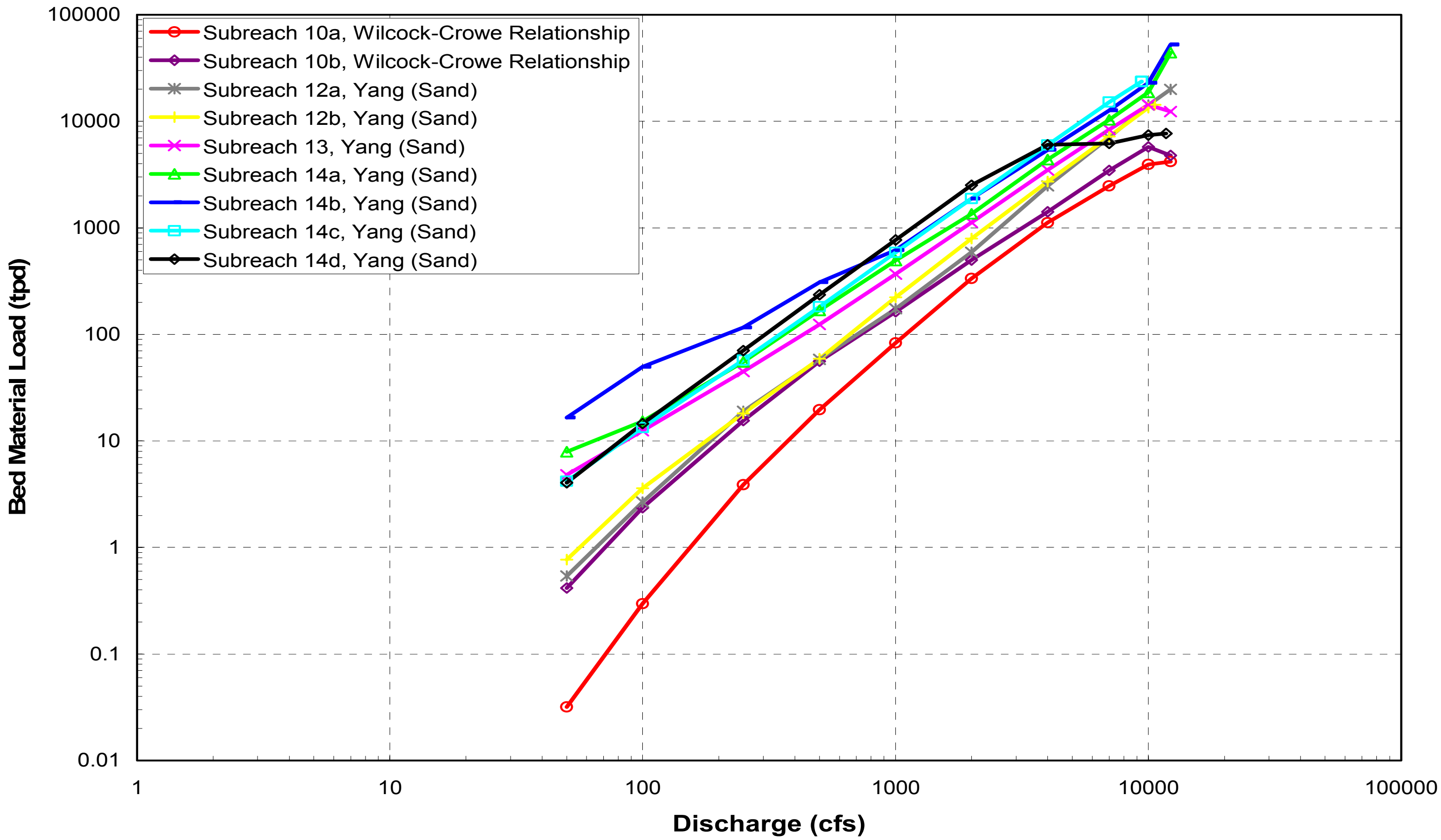


Figure H-1.1 Bed-material rating curves for each of the sediment-continuity subreaches.

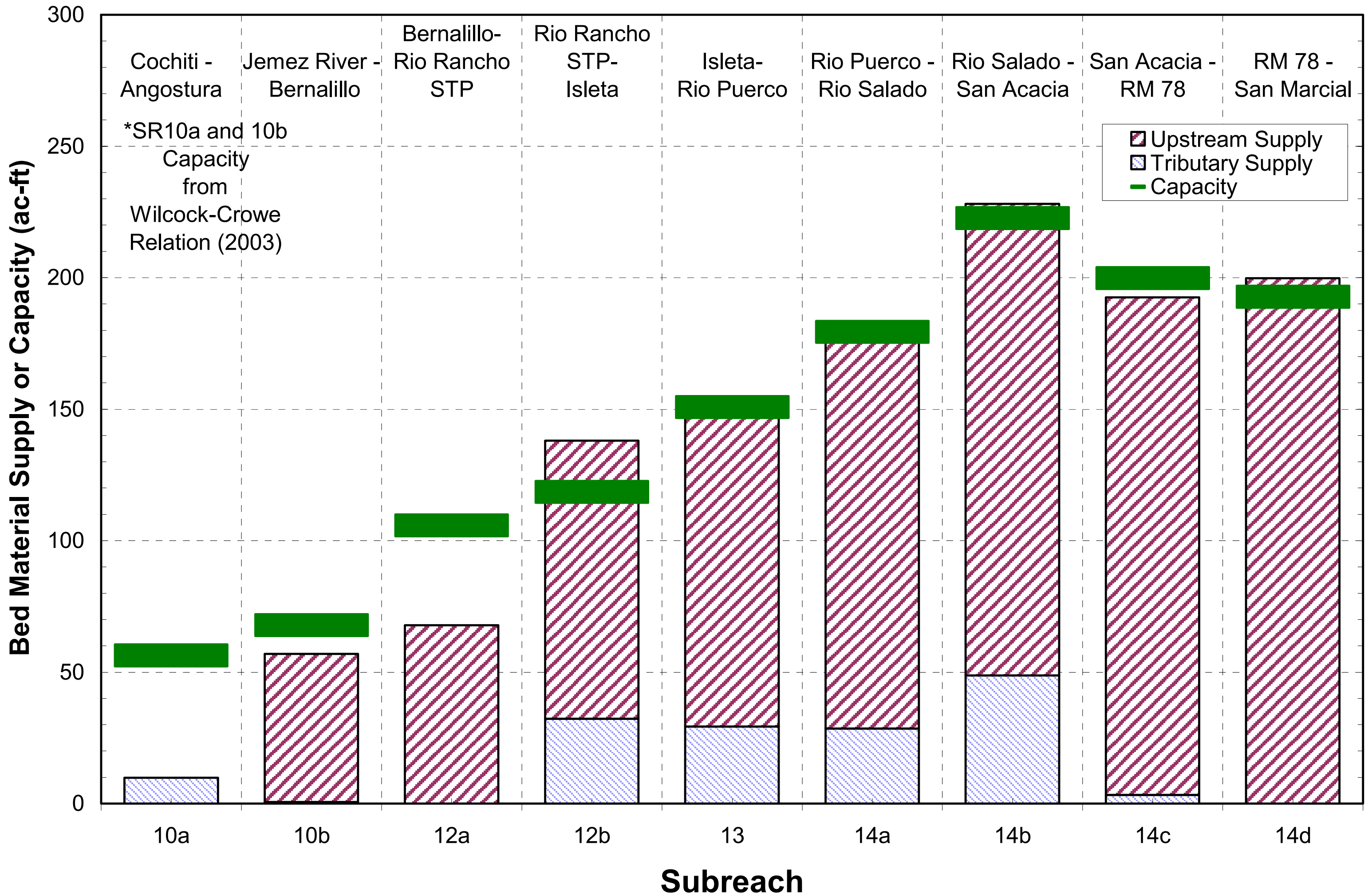


Figure H-1.2 Comparison of annual supply and bed-material transport capacity for each subreach under existing conditions (with no bed-material supply from the Jemez River).

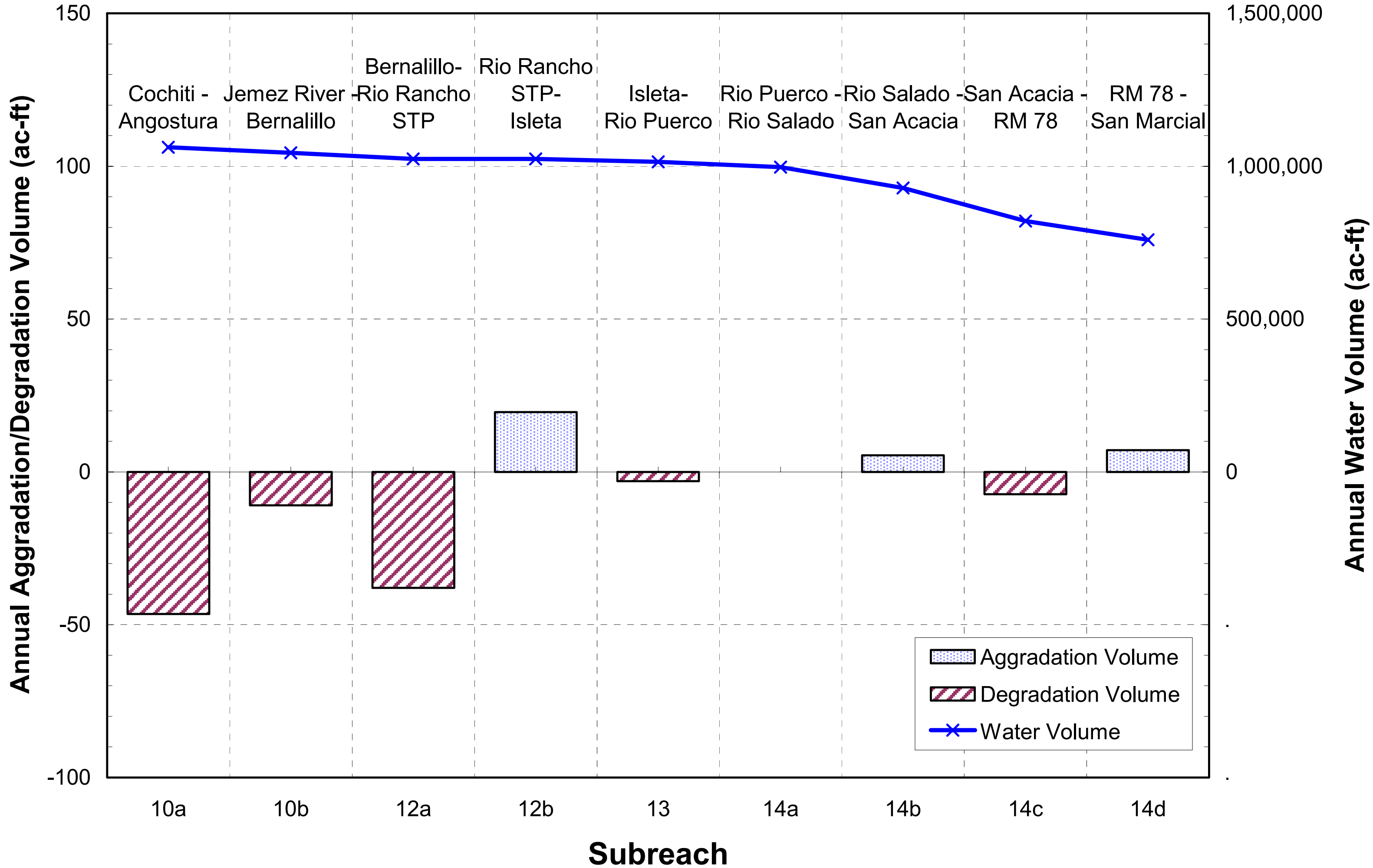


Figure H-1.3 Computed annual aggradation/degradation volumes for each subreach under existing conditions (with no bed-material supply from the Jemez River).

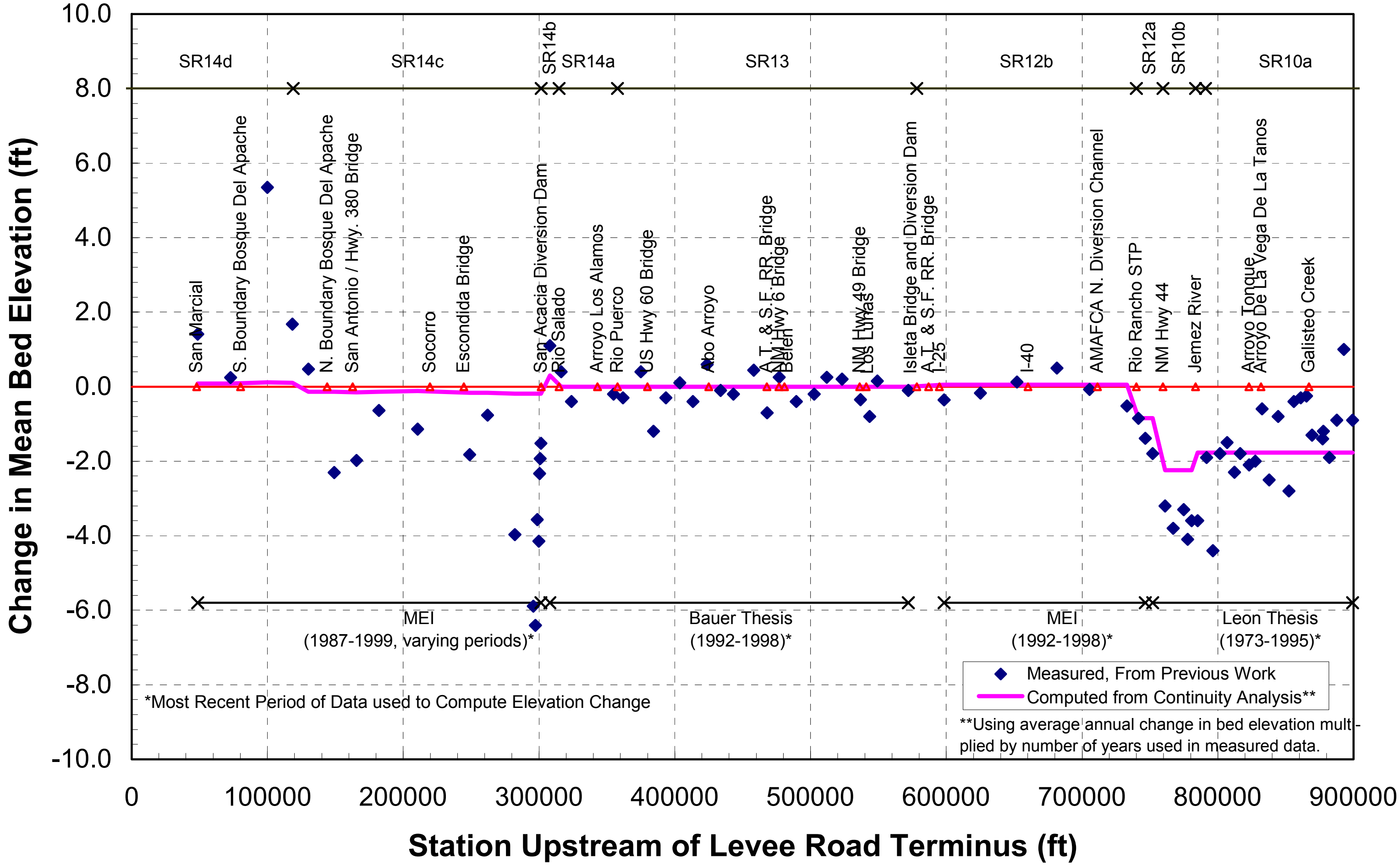


Figure H-1.4 Comparison of measured change in mean bed elevation to the computed change in elevation corresponding to the length of the period of the measured data based on the existing conditions sediment-continuity analysis (with no bed- material supply from the Jemez River).

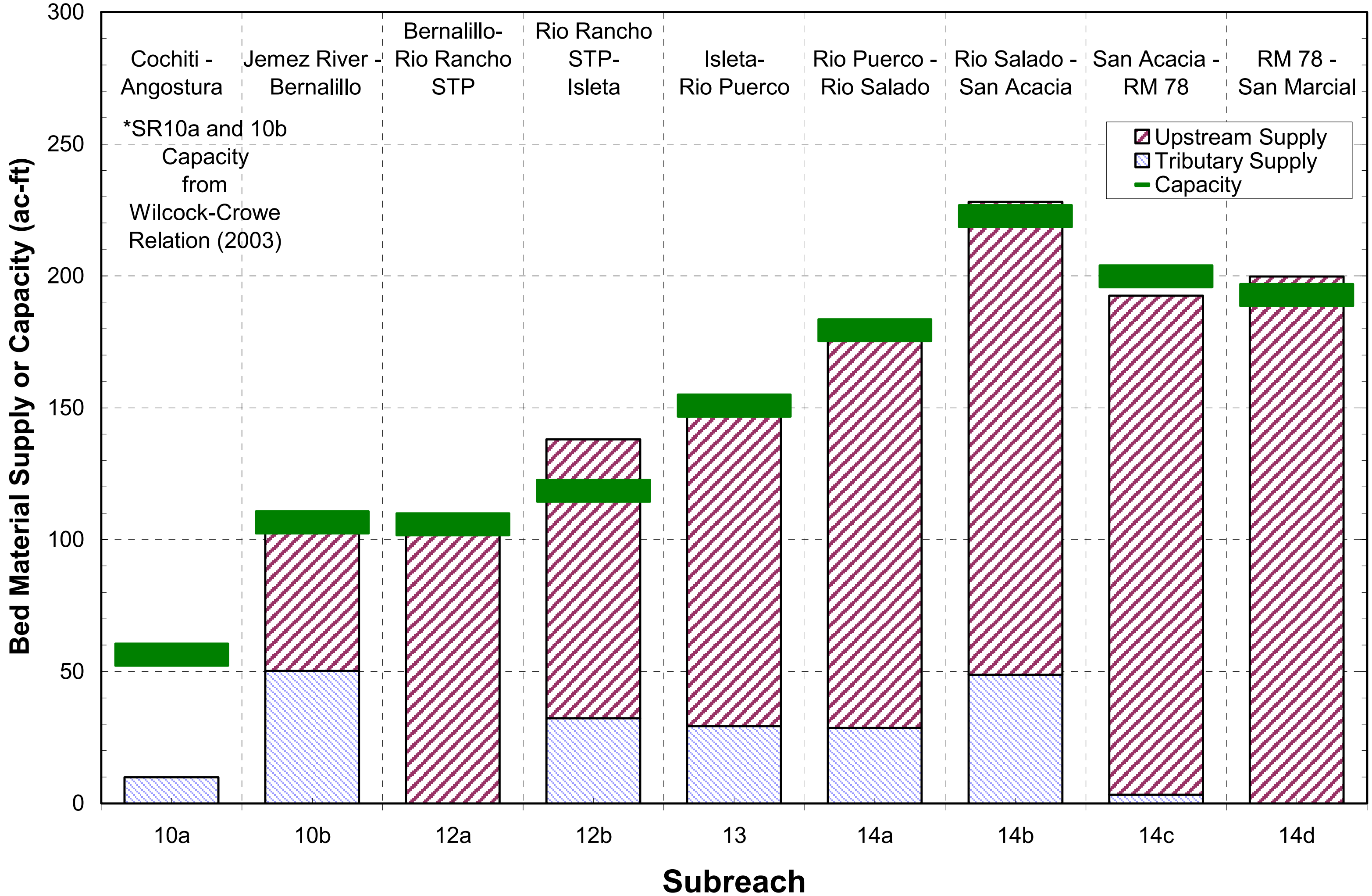


Figure H-1.5 Comparison of annual upstream and tributary bed-material supply with the computed annual transport capacity of each subreach under recent conditions (with 50 ac-ft/yr of bed-material supply from the Jemez River).

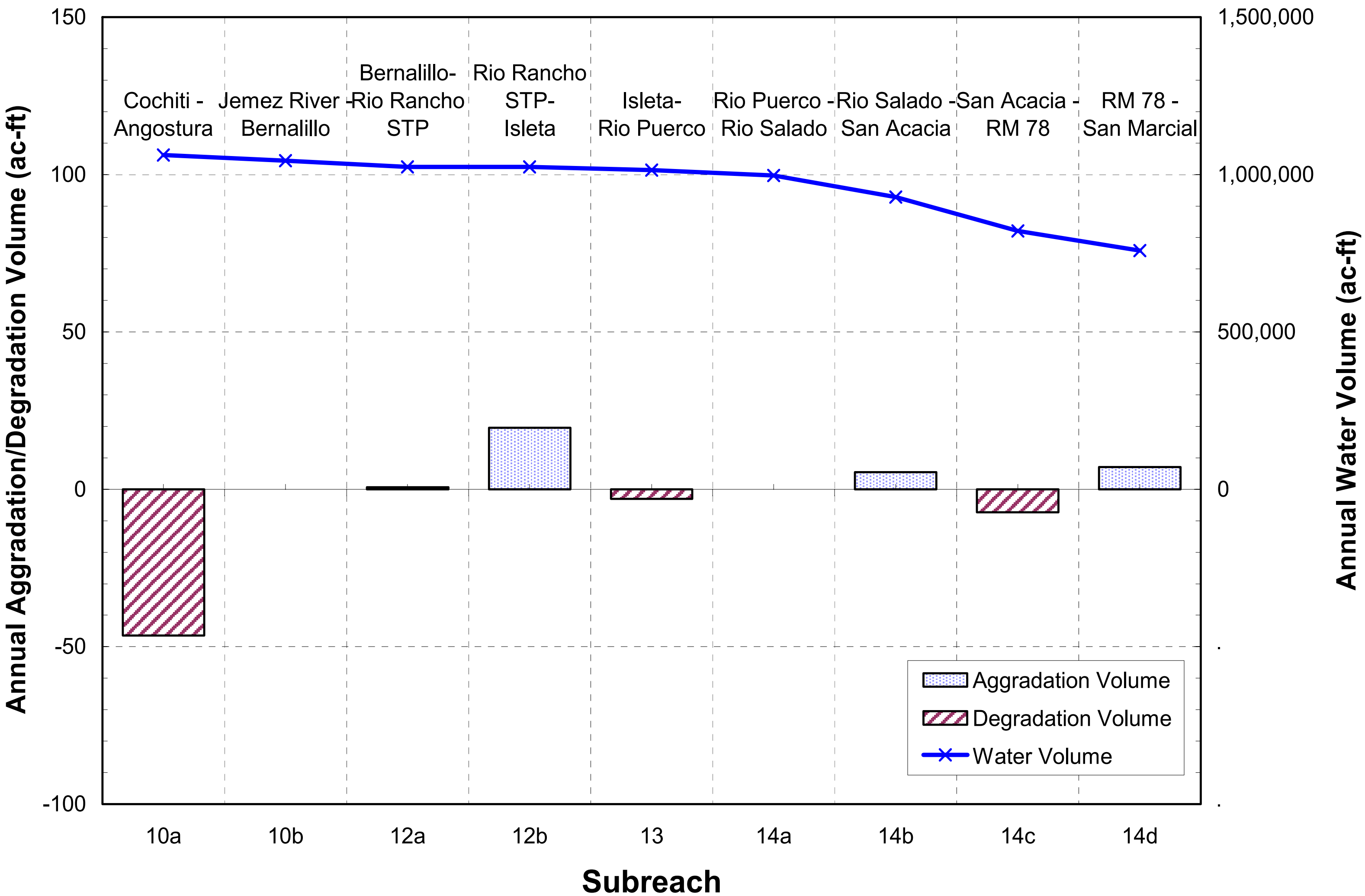
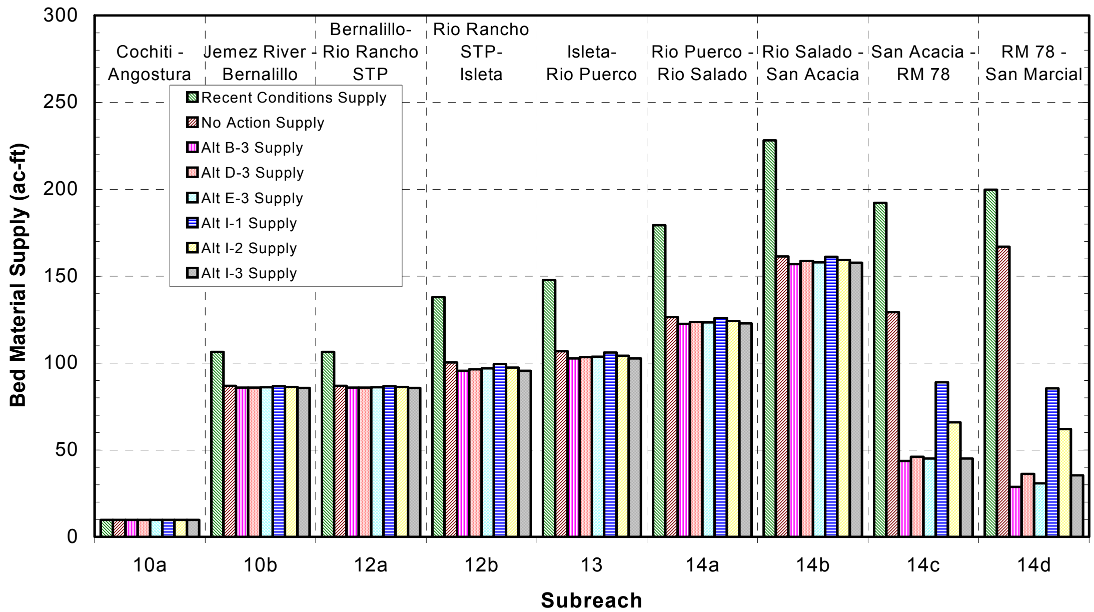


Figure H-1.6 Summary of computed annual aggradation/degradation volumes of each subreach under recent conditions (with 50 ac-ft/yr of bed-material supply from the Jemez River).



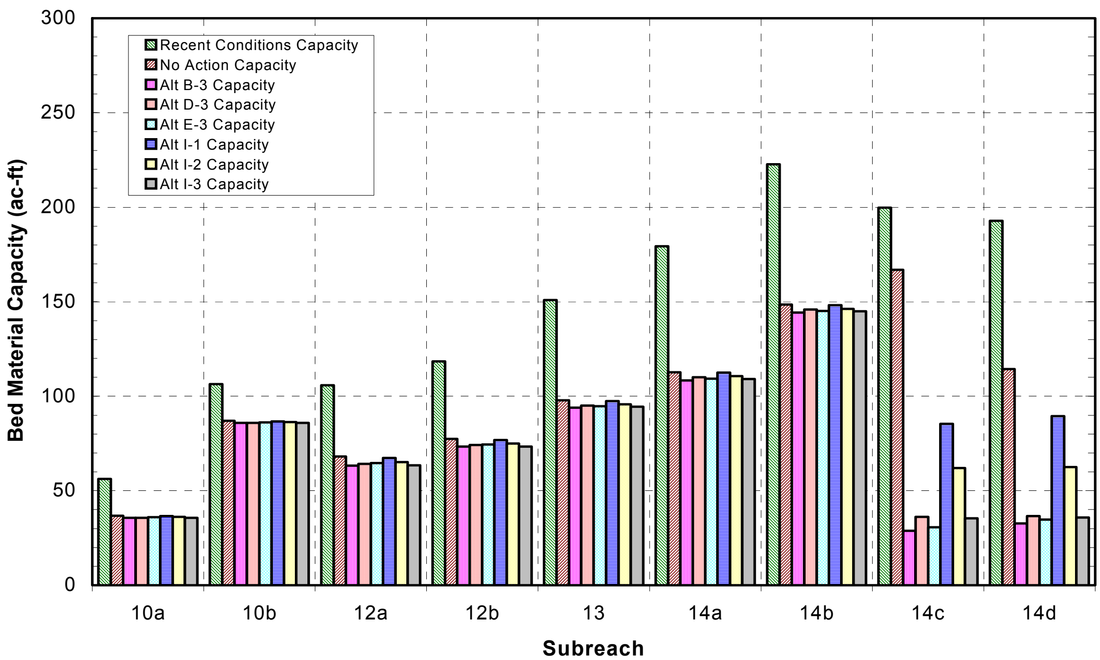


Figure H-1.7 Comparison of annual bed-material supply and computed annual transport capacity for recent conditions (with bed-material supply from the Jemez River) and for the EIS No-Action and Action Alternatives.

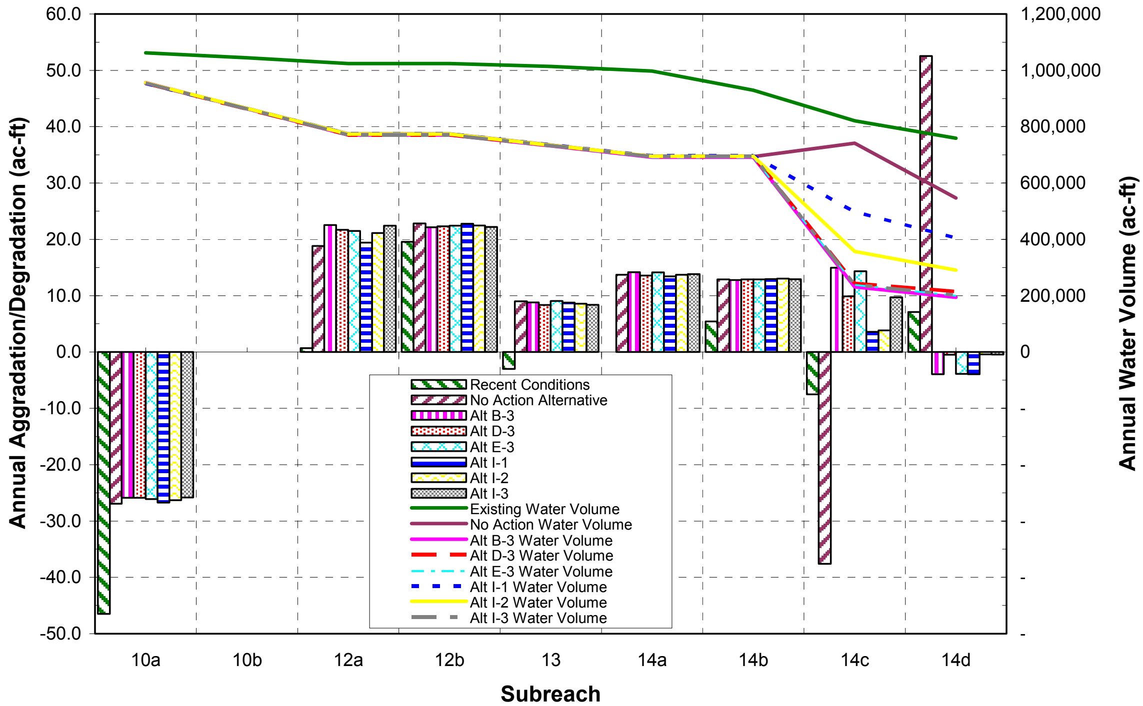


Figure H-1.8 Summary of computed annual aggradation/degradation volumes of each subreach for recent conditions (with bed-material supply from the Jemez River) and the EIS Action and No-Action Alternatives.

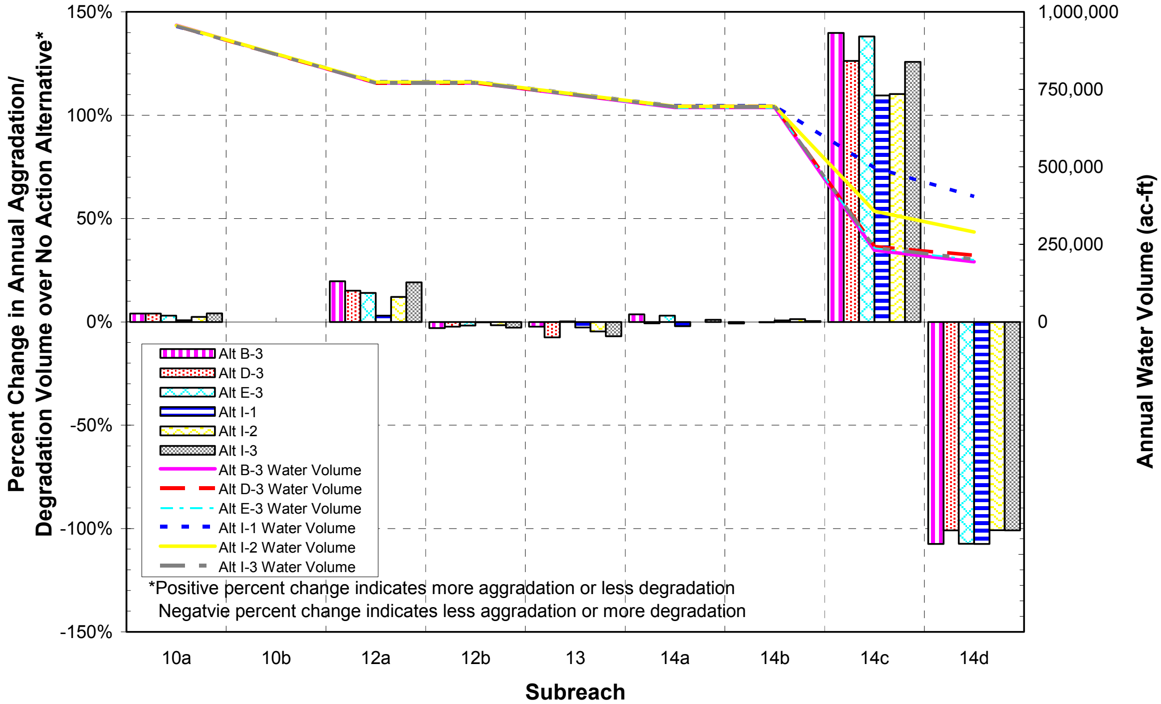


Figure H-1.9 Summary of the percent change in annual aggradation/degradation volumes over the No-Action Alternative for the EIS Action Alternatives, by subreach.

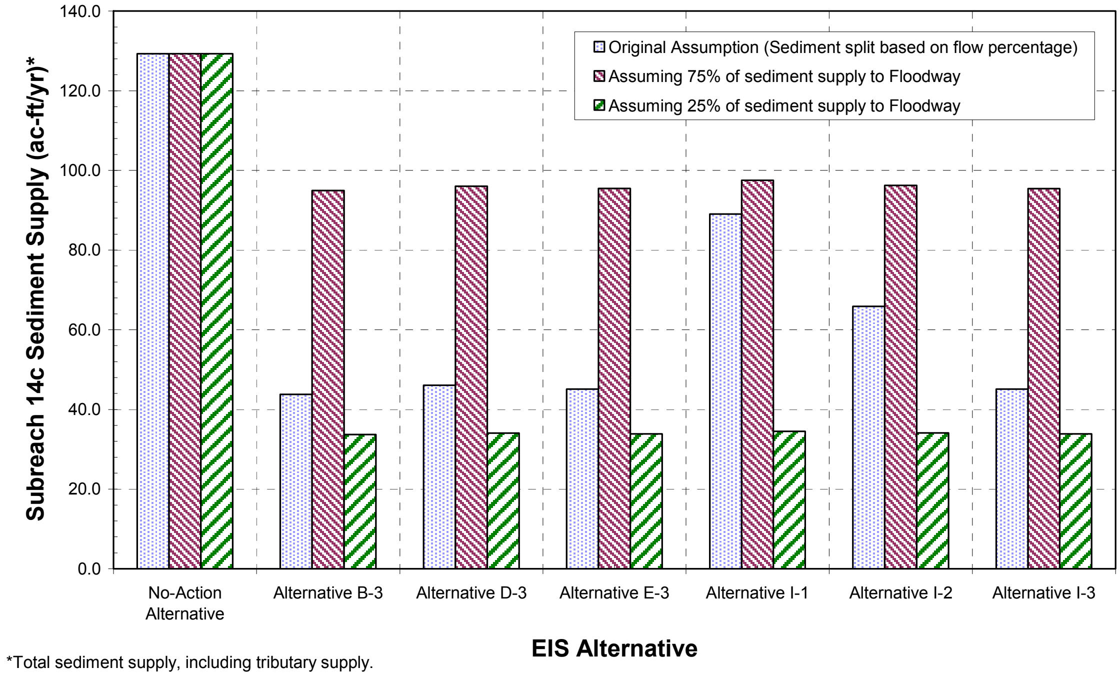


Figure H-1.10 Summary of upstream sediment supply to Subreach 14c for the sensitivity analysis on sediment apportionment at the diversion to the LFCC.

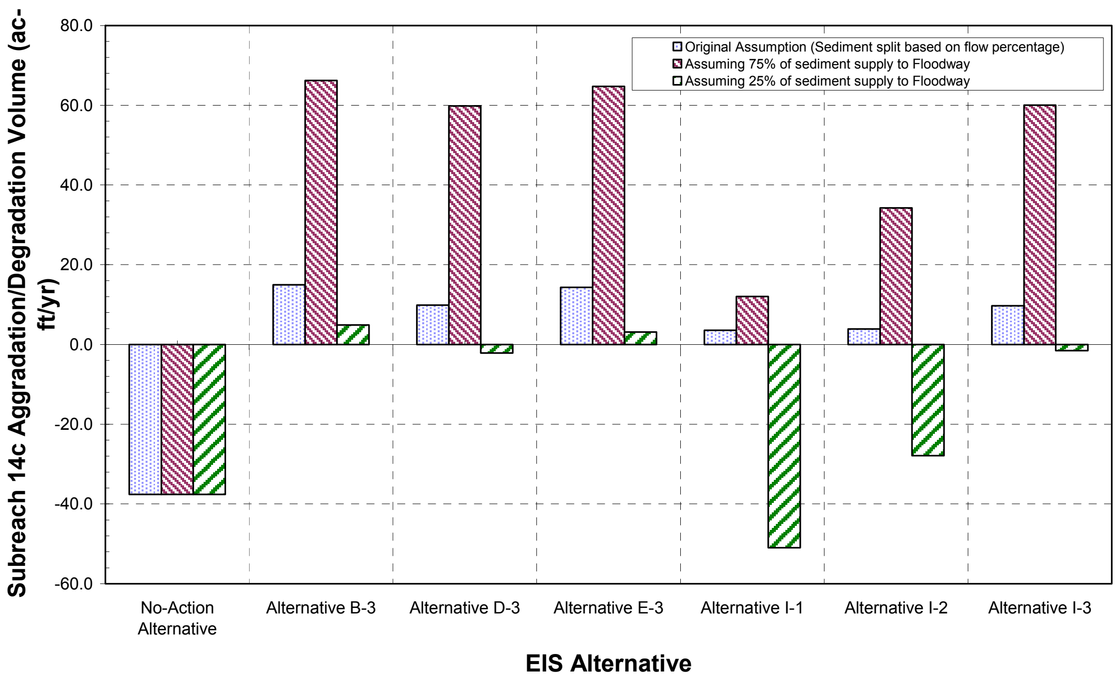


Figure H-1.11 Summary of aggradation/degradation volumes in Subreach 14c for the sensitivity analysis on sediment apportionment at the diversion to the LFCC.

2.0 ANNUAL MAXIMA FREQUENCY ANALYSIS OF THE URGWOM 40-YEAR PLANNING MODEL

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A 40-year planning model of the Upper Rio Grande Water Operations Model (URGWOM) was used to evaluate existing reservoir operations and six alternatives of those operation criteria (B3, D3, E3, I1, I2, and I3; Chapter2: **Table H-2.3** "Summary of Action Alternatives"). Flood frequency analyses were conducted for five gage locations along the Rio Grande based on the URGWOM results (**Table H-2.1**) and are discussed herein.

Instantaneous peak discharge values are generally used for flood frequency analysis. URGWOM, however, produces mean daily values. There are methods of estimating instantaneous peaks based on mean daily values. Usually these estimation techniques rely on scaling the mean daily discharge; the amount of scaling is calibrated using historical data within the system of interest. No estimation of instantaneous peaks was made in this analysis because there exists no data for the reservoir operation alternatives that can be used for calibration. Given the length of record and the method used for estimating flood return periods, described below, actual values of floods and their return periods are insensitive to whether mean or instantaneous peak values are used.

The 40 annual maxima produced by URGWOM are treated as random variables (realizations), which come from a distribution of all possible annual maxima. Physically, the distribution of possible annual maxima is defined by the regulations on the system. The realizations (40 years of annual maxima output by URGWOM) are samples from the true distribution and statistically describe the distribution.

It is assumed that the annual maxima are realizations of Log-Pearson III (LP III) distributions. The actual distributions are defined based on the mean, standard deviation, and skewness observed in the model results. These moments are calculated using the method of moments (MOM) for each alternative and the base case. The actual methodology used for parameter fitting was algorithmically the same as described in the Department of the Interiors Bulleting 17-B. Regional skew was not considered in the analyses because the samples describe regulated systems whereas generalized or regional skews are determined for unregulated systems. The LP III fit to the sample is visually determined to be acceptable for the ranges of interest (1.5 to 10-year return periods) (**Figure H-2.1** through **Figure H-2.35**). Within **Figure H-2.1** through **Figure H-2.35** the effects of the regulation can be seen in the step nature of the data. The LP III distribution is incapable of reproducing these steps. Based on the desire to have the most statistically robust estimates of floods with specific return periods and the sensitivity of estimates of this type when using an alternative plotting position techniques the results presented are considered to be the best available. Based on the LP III distributions fit to the sample data, values of discharges with probabilities of being exceeded every 1.5, 2, 5, and 10 years are presented in **Table H-2.1** for each gage location and each alternative as well as the baseline scenario.

Table H-2.1 U.S. Geological Survey streamflow-gaging stations for each study reach.

STATION NUMBER	STATION NAME	REACH
08319000	Rio Grande at San Felipe	10
08330000	Rio Grande at Albuquerque	12
08332010	Rio Grande near Bernardo	13
08354900	Rio Grande at San Acacia	14
08358400	Rio Grande at San Marcial	14

Table H-2.2 Selected return period data annual maximum discharge for the various alternatives and the basline condition for streamflow-gaging stations.

	Rio Grande at San Felipe (08319000)							
		B3	D3	E3	I1	I2	I3	Baseline
Return Period	1.5	2,860	2,970	2,950	3,190	3,090	2,950	3,190
	2	3,670	3,770	3,800	4,040	3,910	3,730	4,040
	5	5,700	5,610	5,970	5,870	5,730	5,550	5,850
	10	7,040	6,700	7,410	6,860	6,760	6,630	6,830

	Rio Grande at Albuqurque (08330000)							
		B3	D3	E3	I1	I2	I3	Baseline
Return Period	1.5	2,595	2,690	2,672	2,867	2,768	2,669	2,873
	2	3,444	3,521	3,573	3,754	3,625	3,488	3,761
	5	5,588	5,417	5,867	5,671	5,533	5,356	5,674
	10	6,974	6,498	7,359	6,685	6,588	6,423	6,683

	Rio Grande Floodway near Bernardo (08332010)							
		B3	D3	E3	I1	I2	I3	Baseline
Return Period	1.5	2,600	2,690	2,670	2,870	2,770	2,670	2,870
	2	3,440	3,520	3,570	3,750	3,630	3,490	3,760
	5	5,590	5,420	5,870	5,670	5,530	5,360	5,670
	10	6,970	6,500	7,360	6,690	6,590	6,420	6,680

	Rio Grande at San Acacia (08354900)							
		B3	D3	E3	I1	I2	I3	Baseline
Return Period	1.5	740	820	810	2,280	1,600	800	2,830
	2	1,200	1,290	1,300	3,080	2,410	1,250	3,600
	5	2,960	2,940	3,210	4,950	4,490	2,870	5,370
	10	4,700	4,380	5,070	6,030	5,720	4,300	6,440

	Rio Grande at San Marcial (08358400)							
		B3	D3	E3	I1	I2	I3	Baseline
Return Period	1.5	960	1,020	1,010	2,000	1,550	1,000	2,190
	2	1,400	1,480	1,500	2,700	2,210	1,440	2,890
	5	2,990	2,920	3,220	4,460	3,980	2,870	4,610
	10	4,470	4,130	4,820	5,570	5,170	4,070	5,710

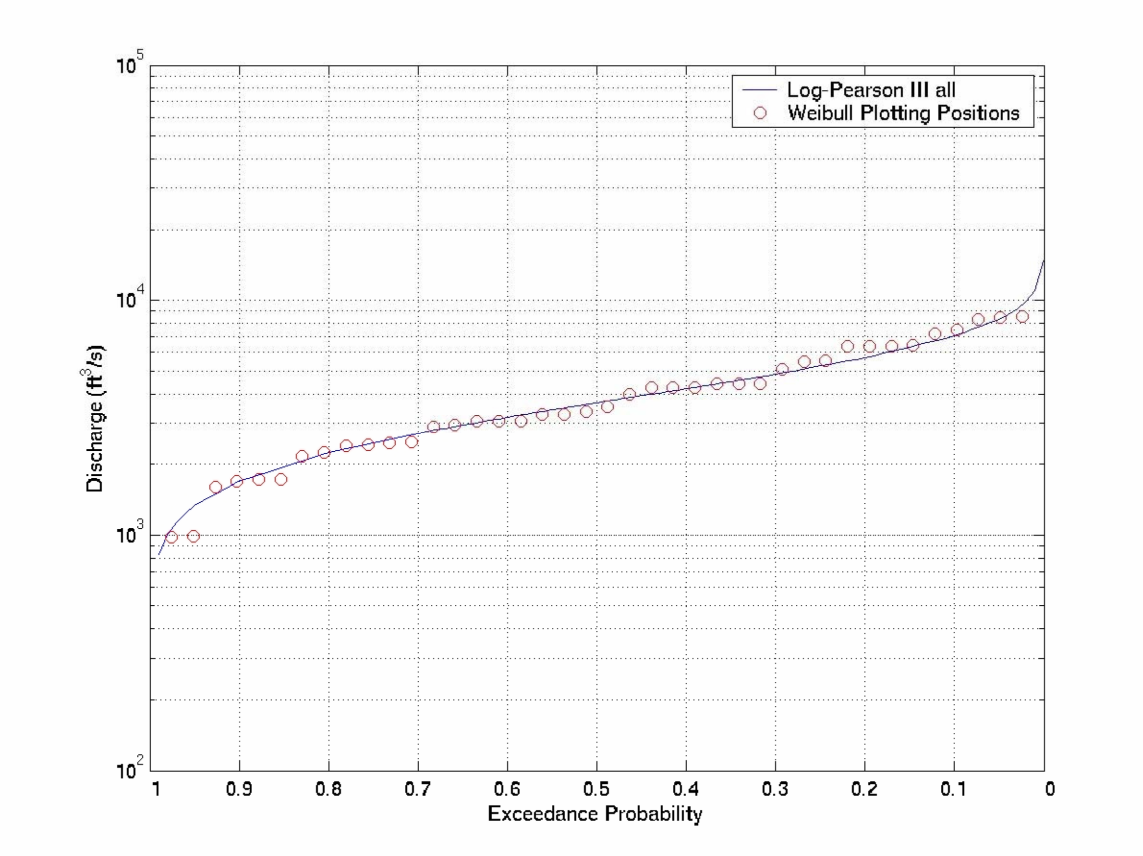

Figure H-2.1 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Felipe, New Mexico 08319000 for planning model alternative B3.

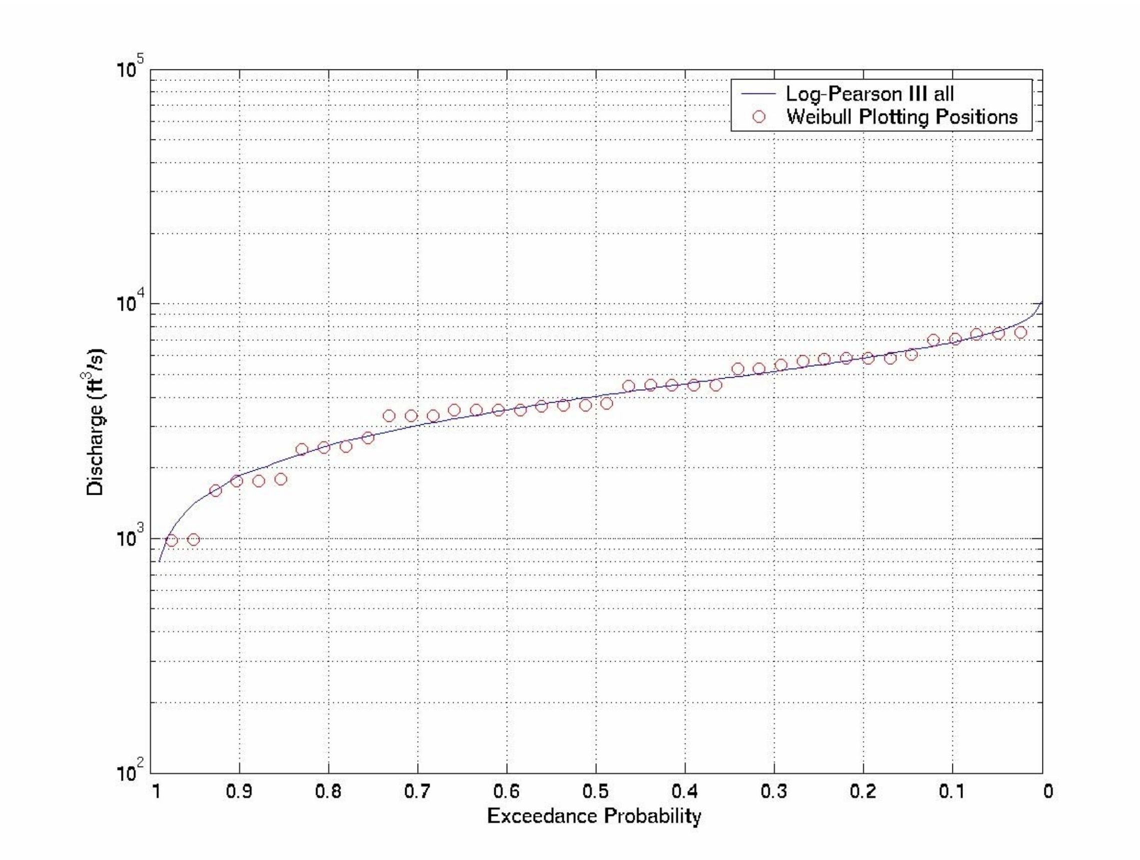

Figure H-2.2 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Felipe, New Mexico 08319000 for planning model alternative baseline.

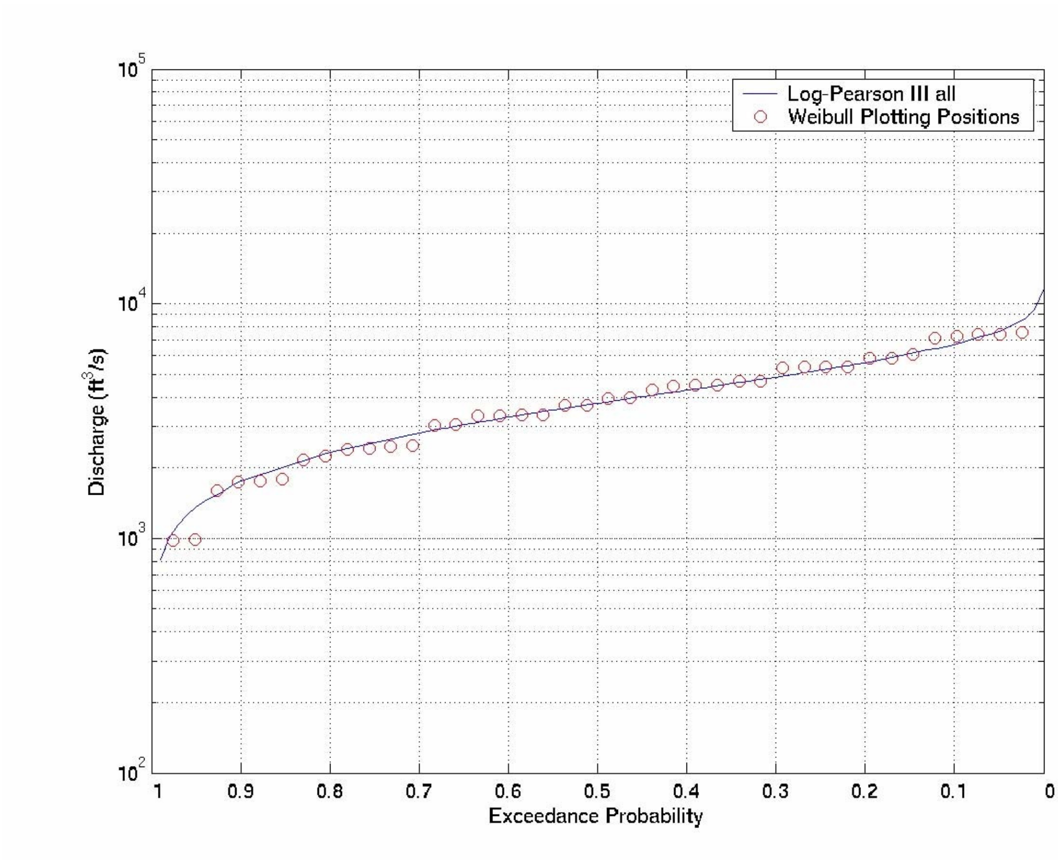

Figure H-2.3 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Felipe, New Mexico 08319000 for planning model alternative D3.

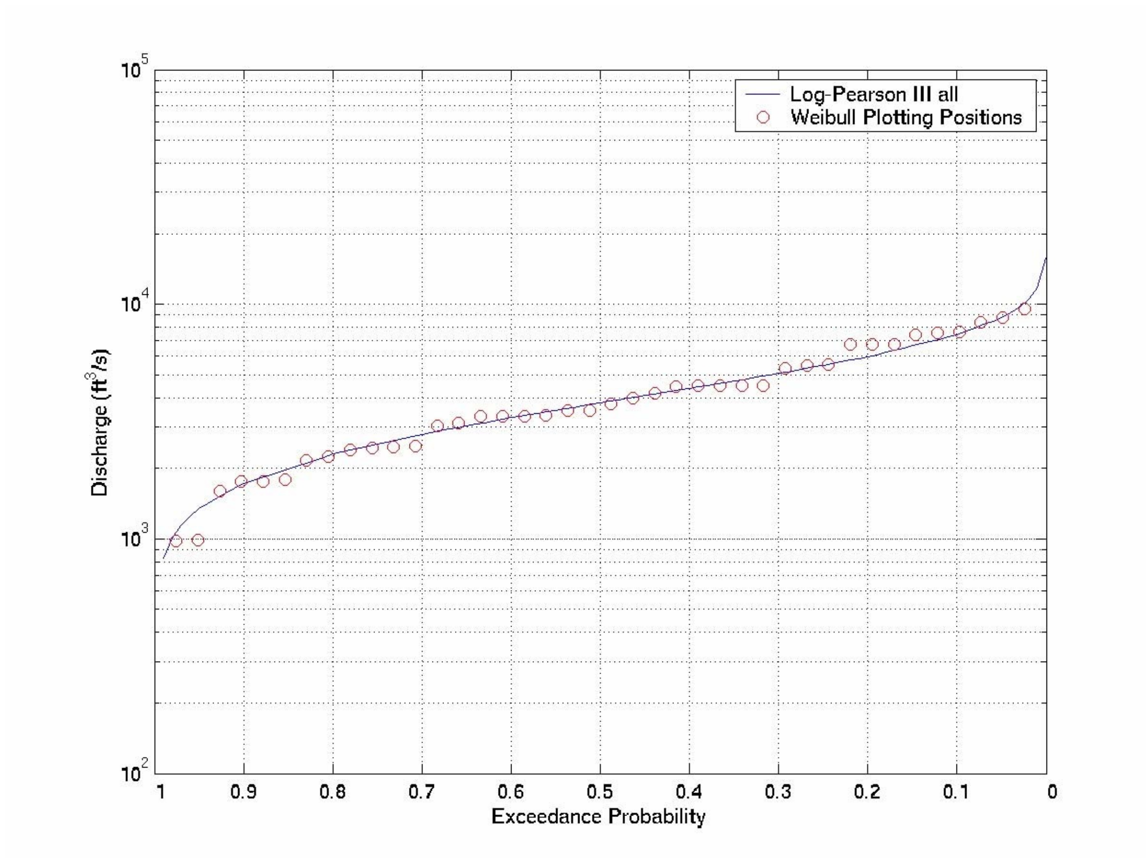

Figure H-2.4 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Felipe, New Mexico 08319000 for planning model alternative E3.

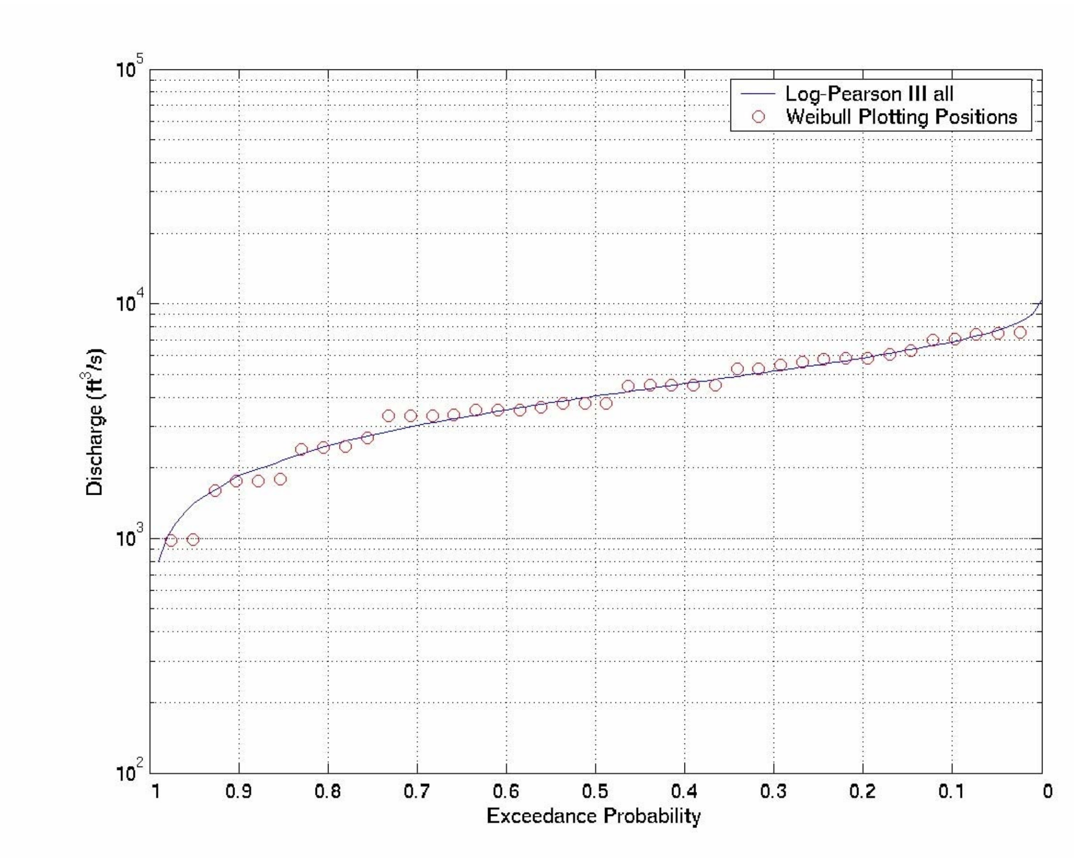

Figure H-2.5 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Felipe, New Mexico 08319000 for planning model alternative I1.

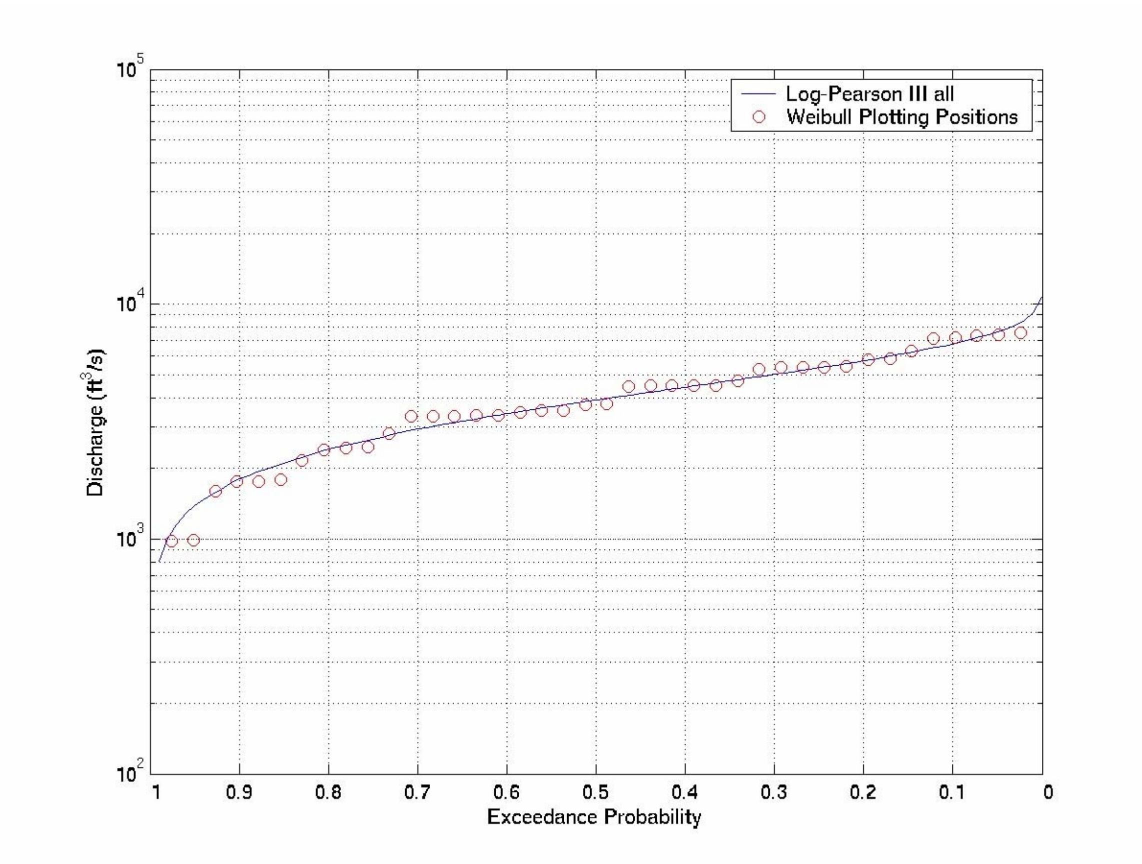

Figure H-2.6 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Felipe, New Mexico 08319000 for planning model alternative I2.

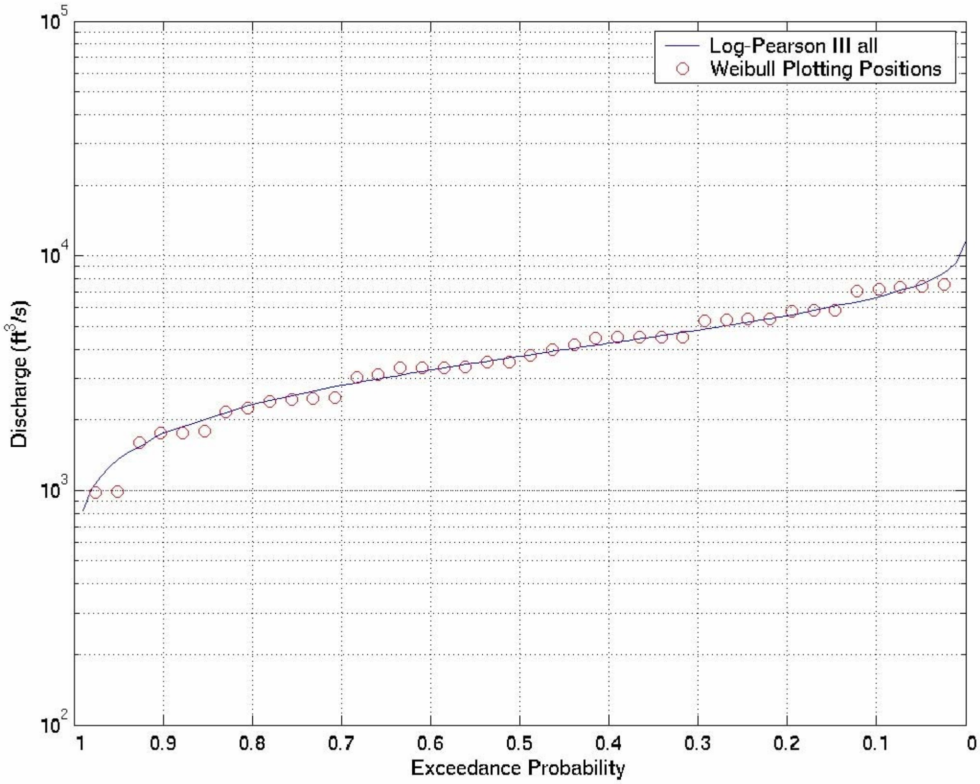

Figure H-2.7 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Felipe, New Mexico 08319000 for planning model alternative I3.

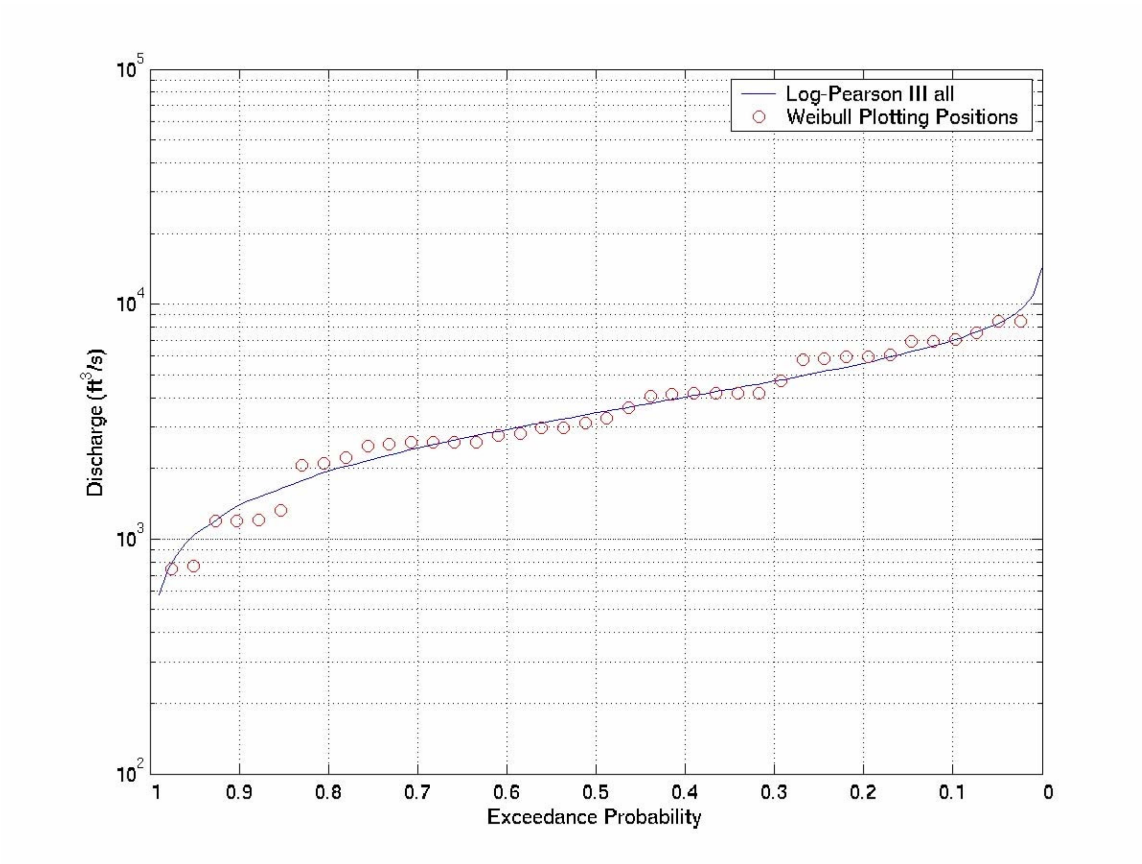

Figure H-2.8 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at Albuquerque, New Mexico 08330000 for planning model alternative B3.

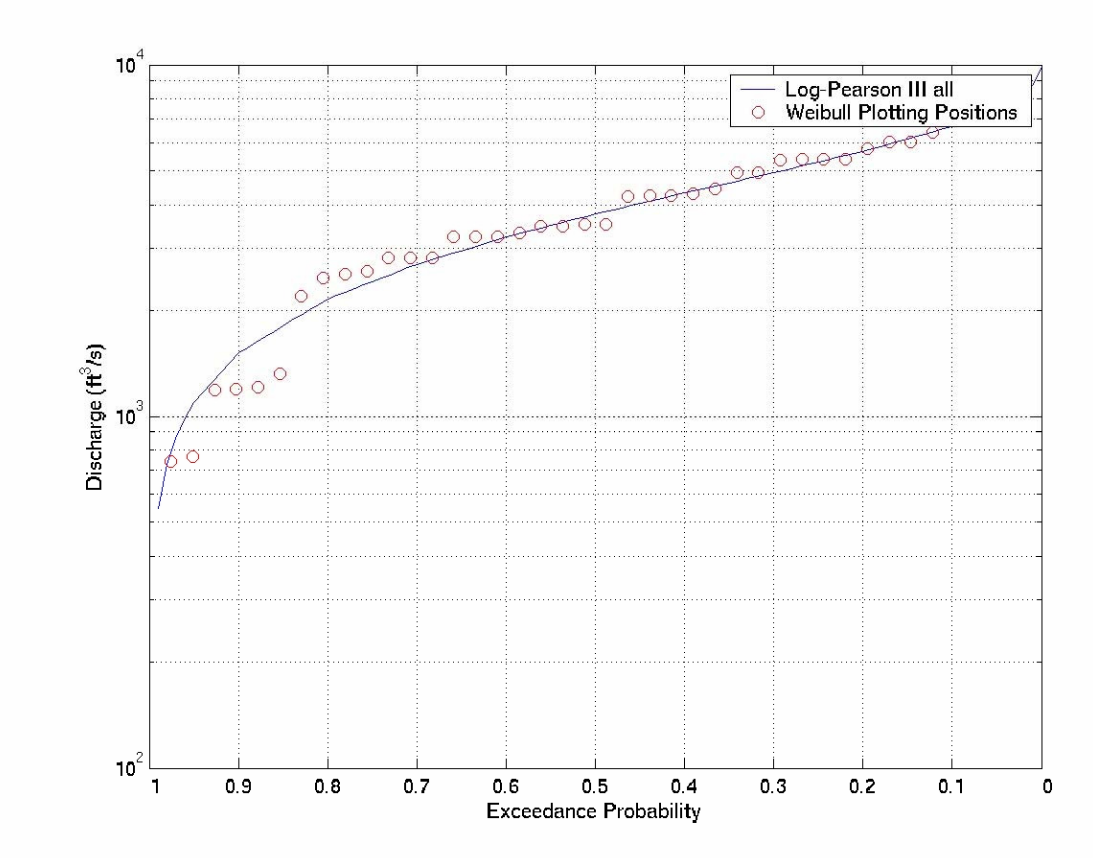

Figure H-2.9 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at Albuquerque, New Mexico 08330000 for planning model alternative baseline.

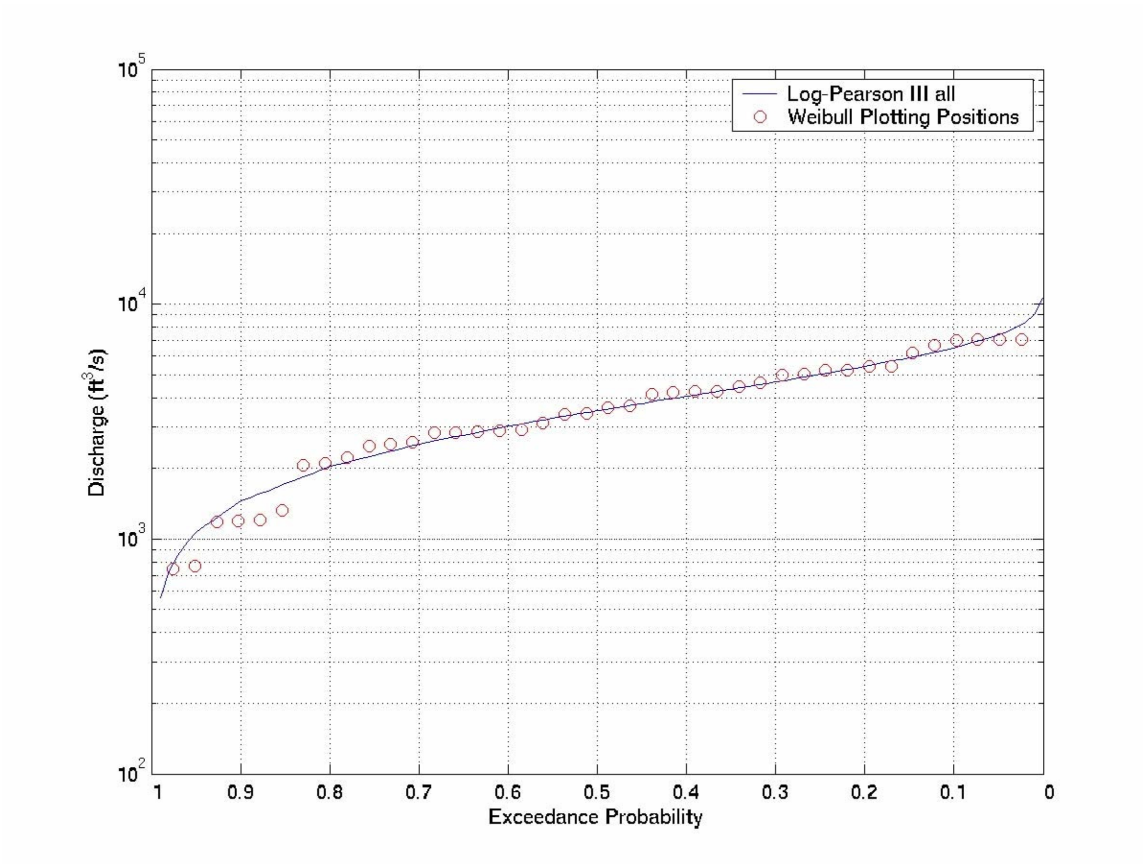

Figure H-2.10 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at Albuquerque, New Mexico 08330000 for planning model alternative D3.

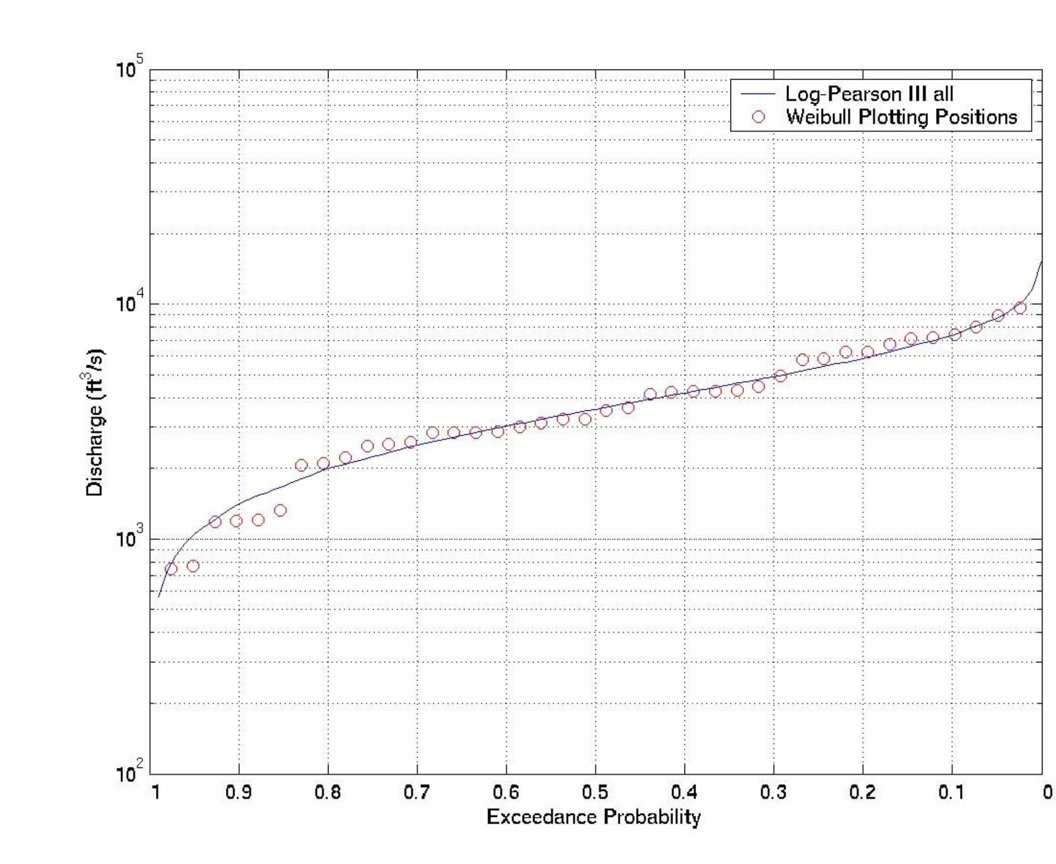

Figure H-2.11 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at Albuquerque, New Mexico 08330000 for planning model alternative E3.

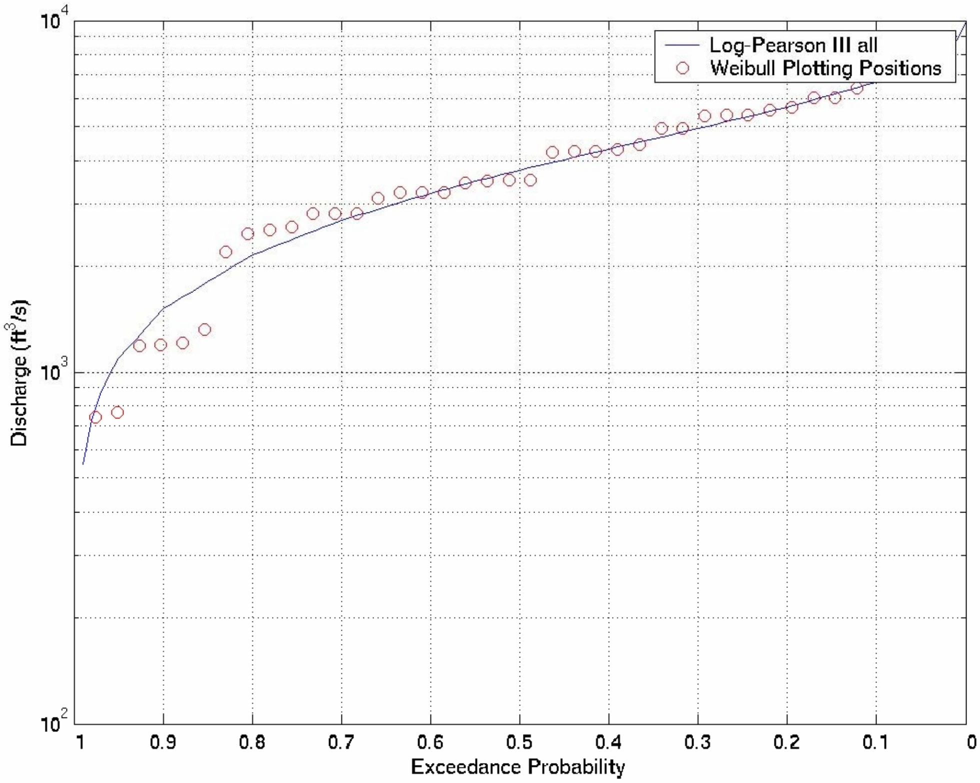

Figure H-2.12 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at Albuquerque, New Mexico 08330000 for planning model alternative I1.

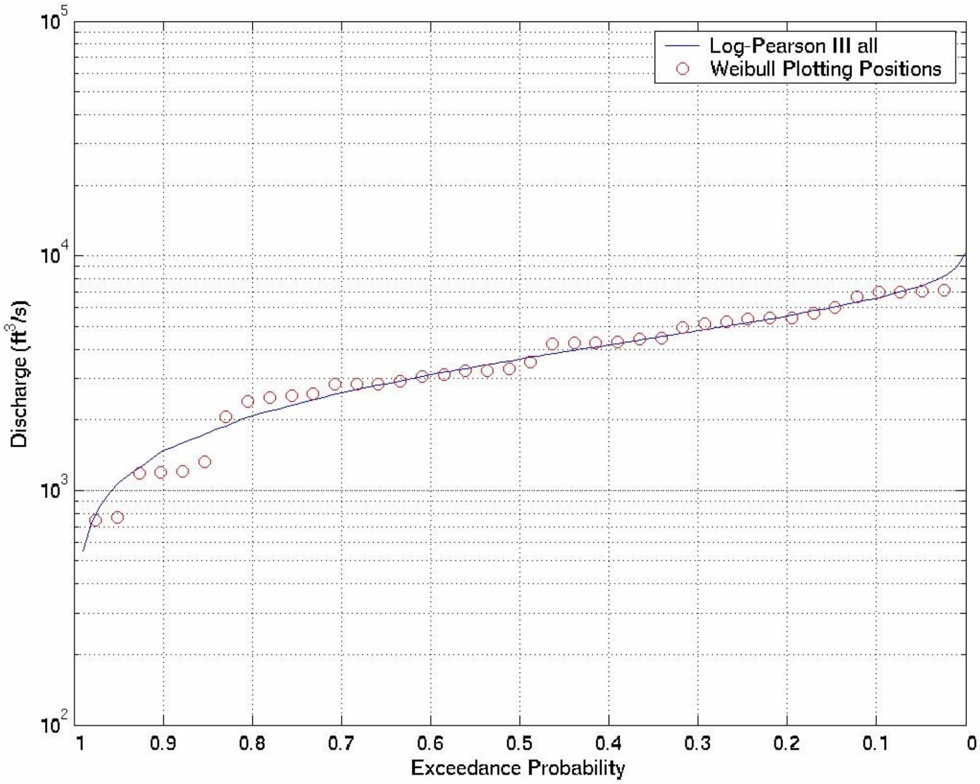

Figure H-2.13 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at Albuquerque, New Mexico 08330000 for planning model alternative I2.

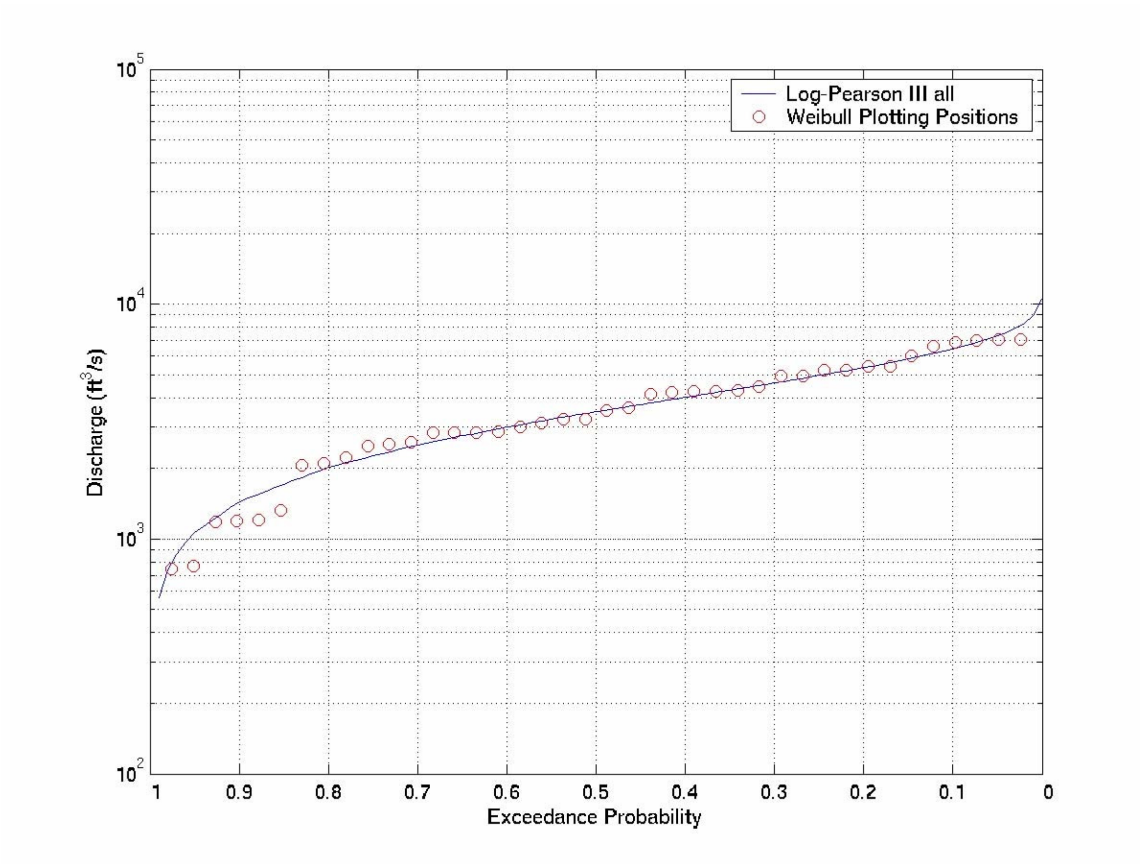

Figure H-2.14 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at Albuquerque, New Mexico 08330000 for planning model alternative I3.

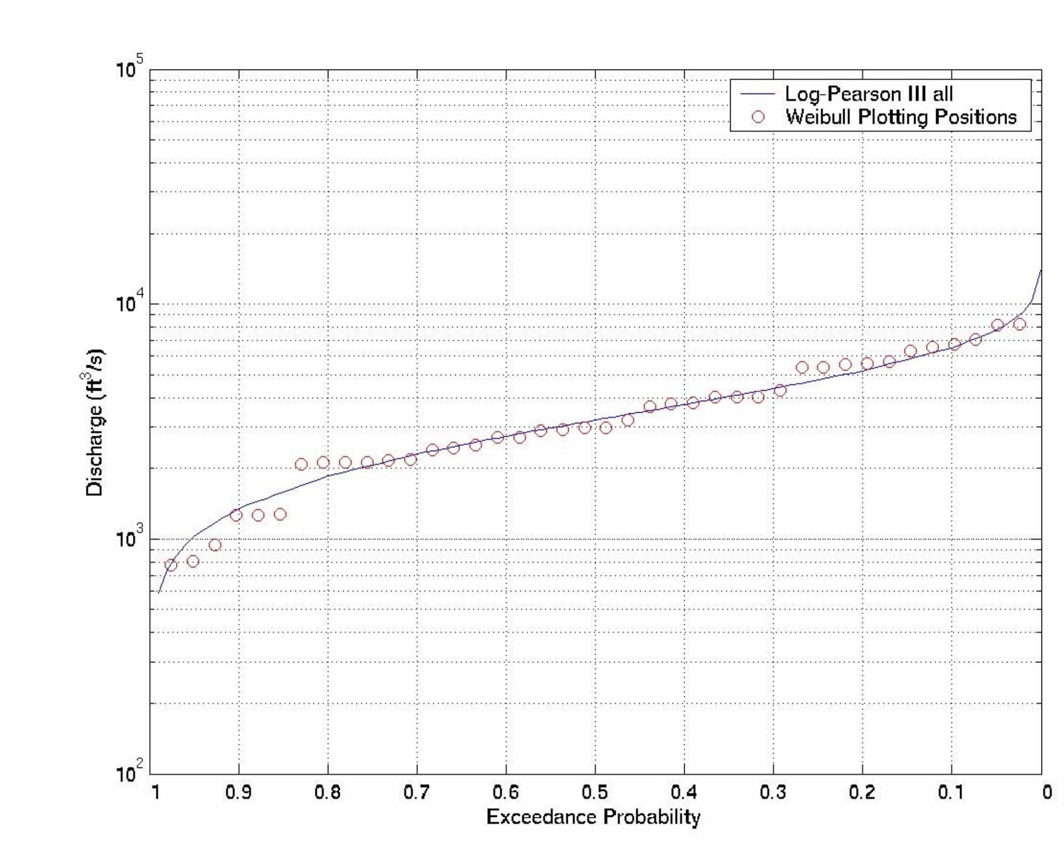

Figure H-2.15 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway near Bernardo, New Mexico 08332010 for planning model alternative B3.

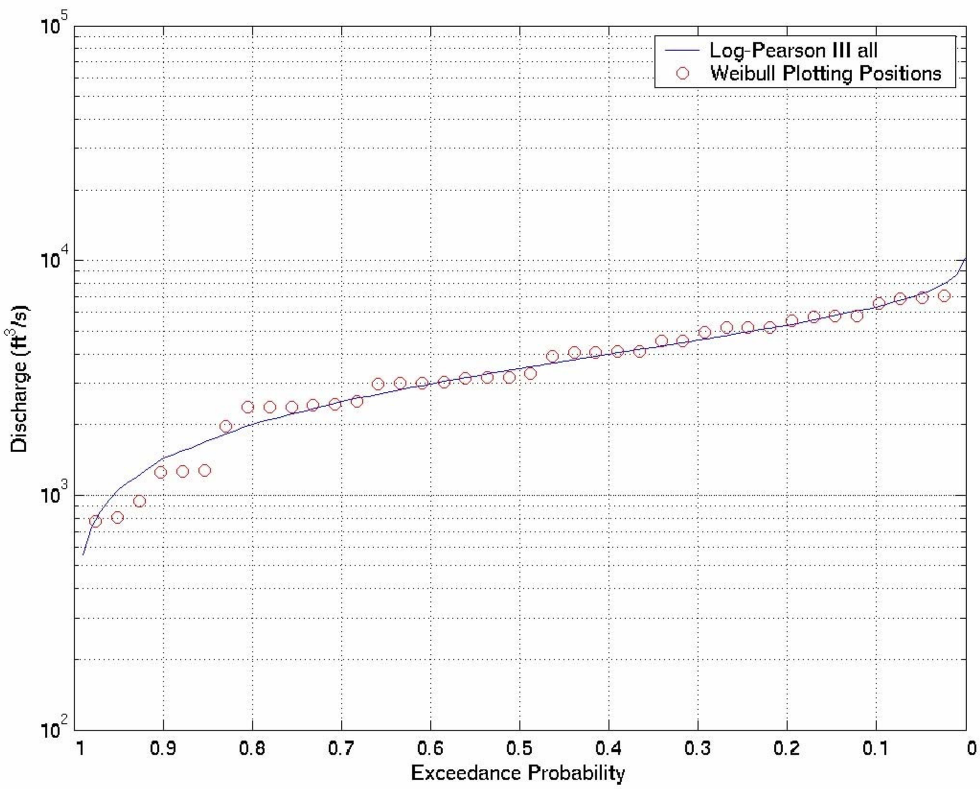

Figure H-2.16 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway near Bernardo, New Mexico 08332010 for planning model alternative baseline.

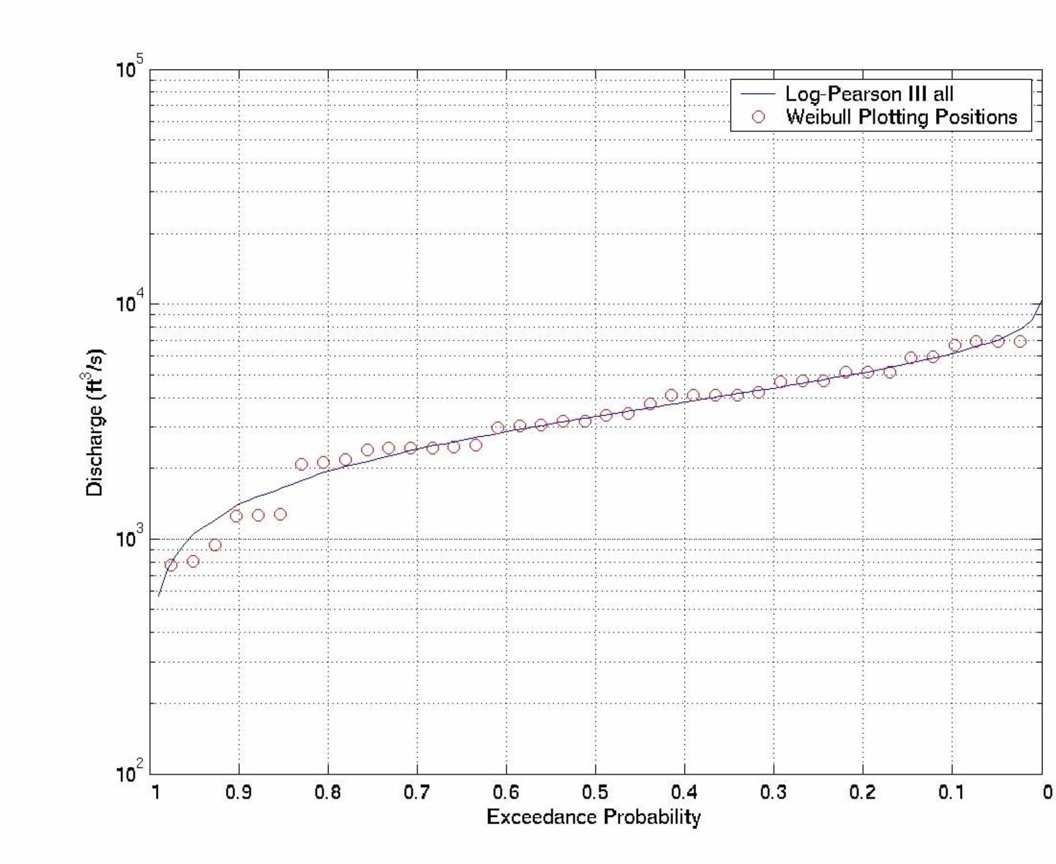

Figure H-2.17 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway near Bernardo, New Mexico 08332010 for planning model alternative D3.

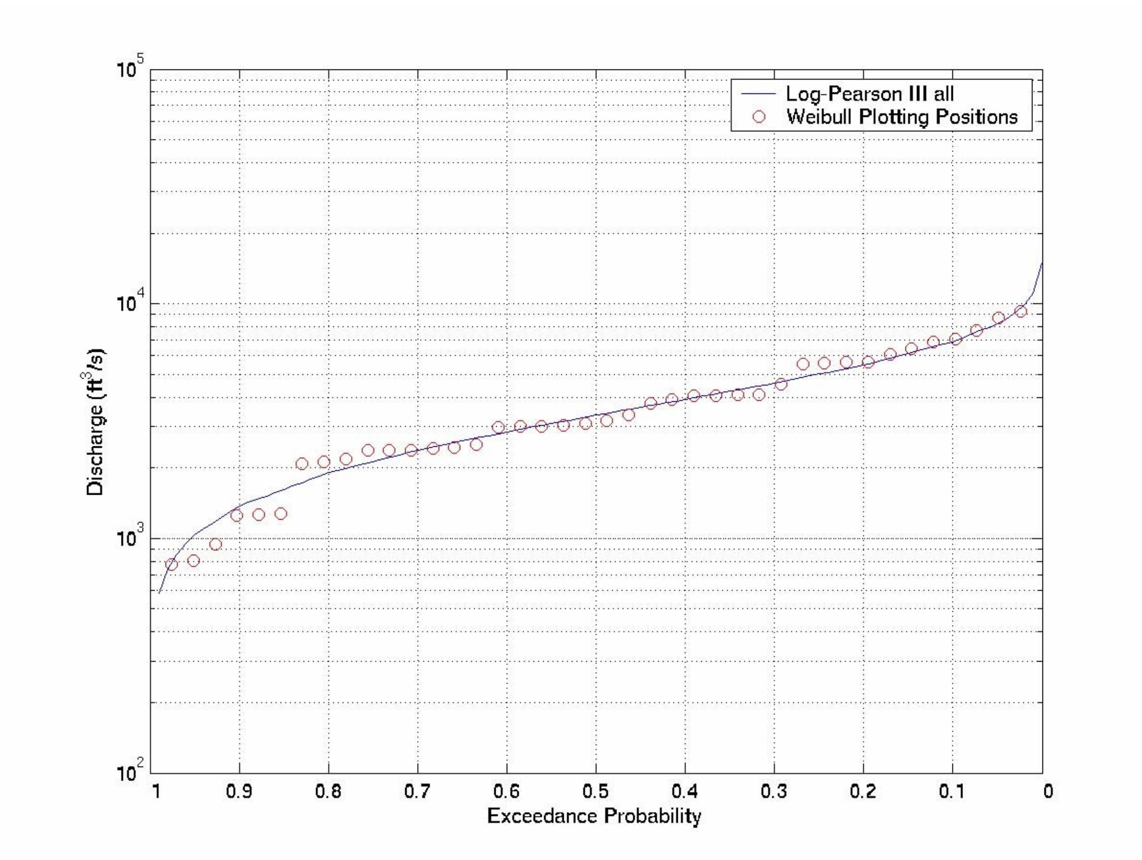

Figure H-2.18 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway near Bernardo, New Mexico 08332010 for planning model alternative E3.

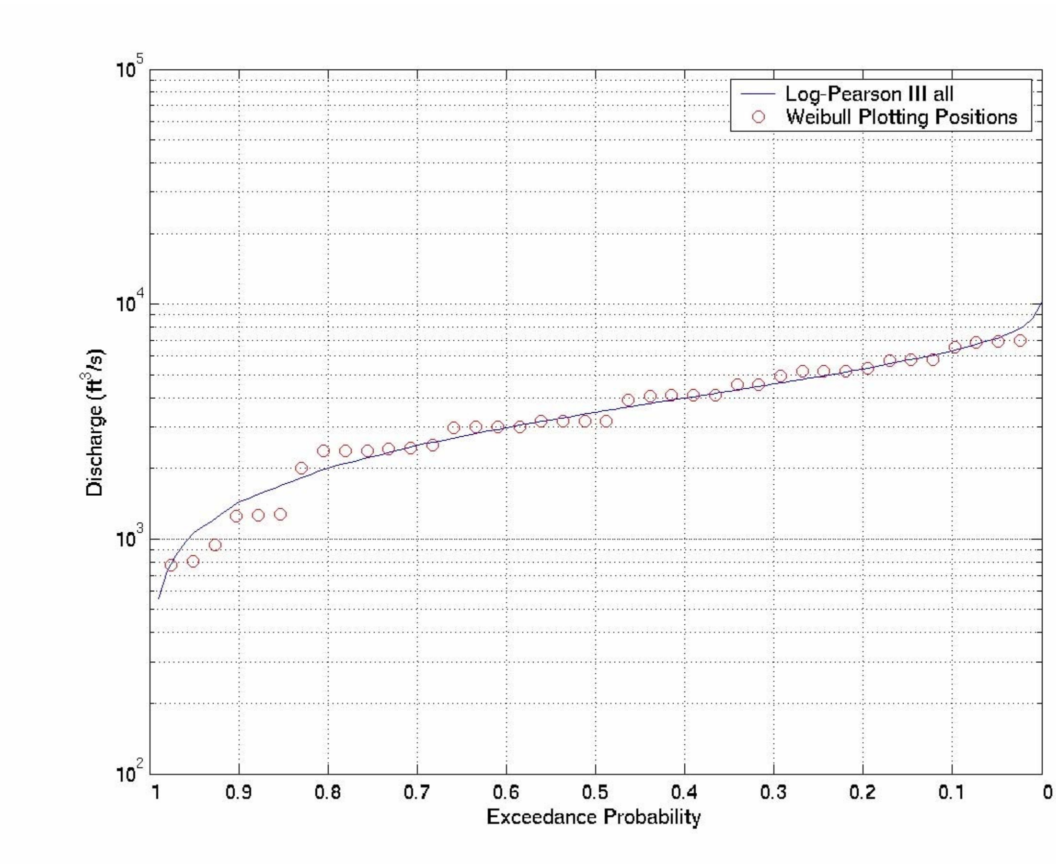

Figure H-2.19 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway near Bernardo, New Mexico 08332010 for planning model alternative I1.

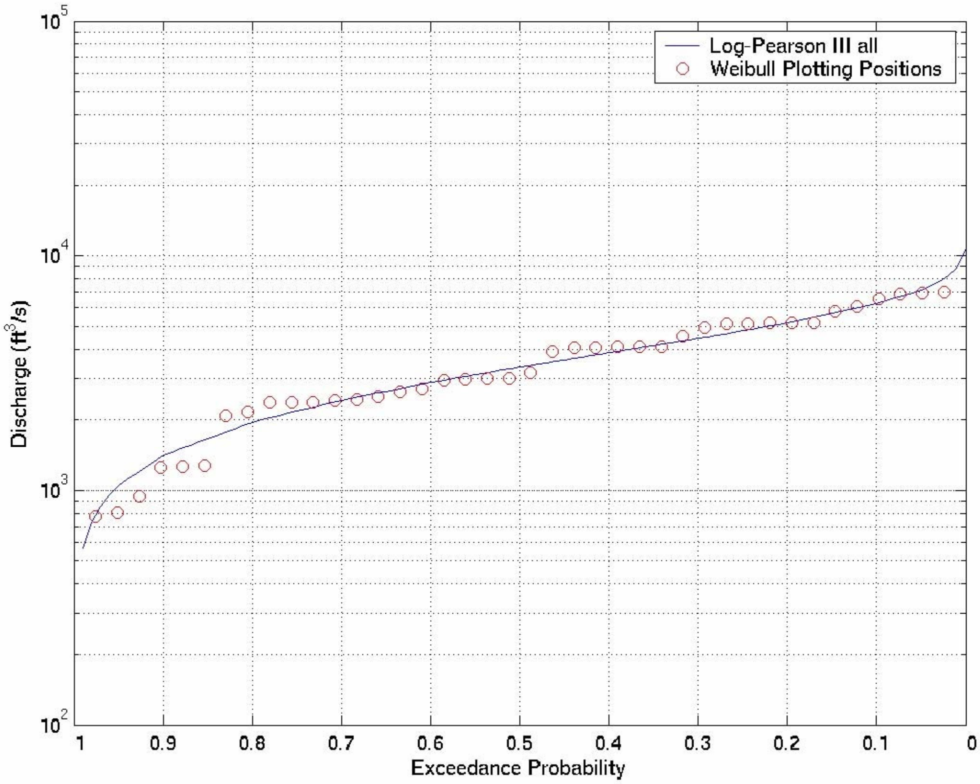

Figure H-2.20 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway near Bernardo, New Mexico 08332010 for planning model alternative I2.

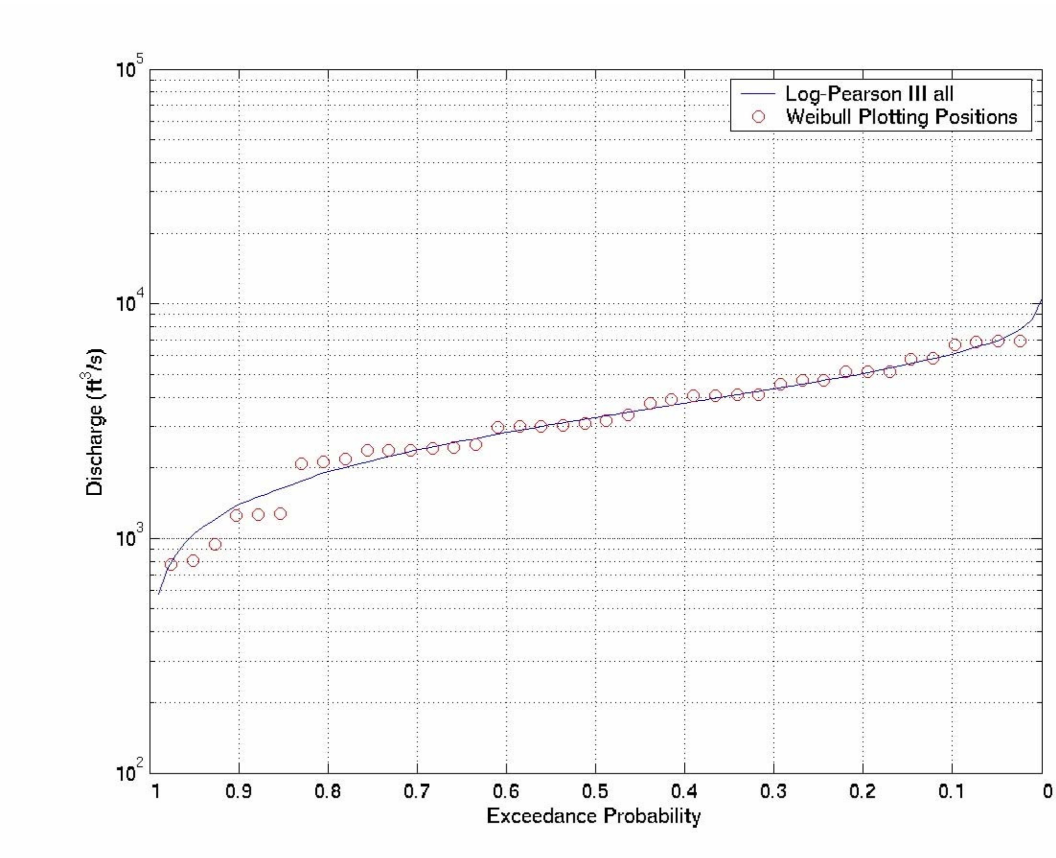

Figure H-2.21 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway near Bernardo, New Mexico 08332010 for planning model alternative I3.

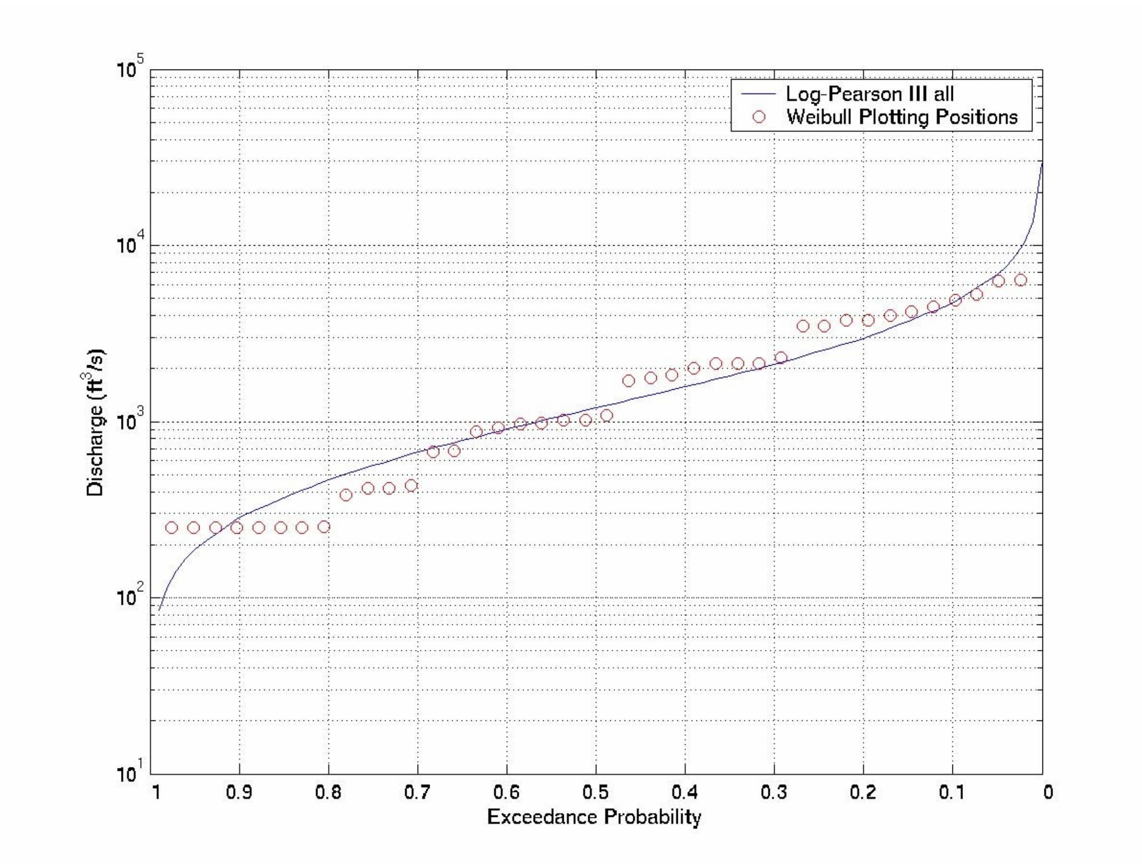

Figure H-2.22 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Acacia, New Mexico 08354900 for planning model alternative B3.

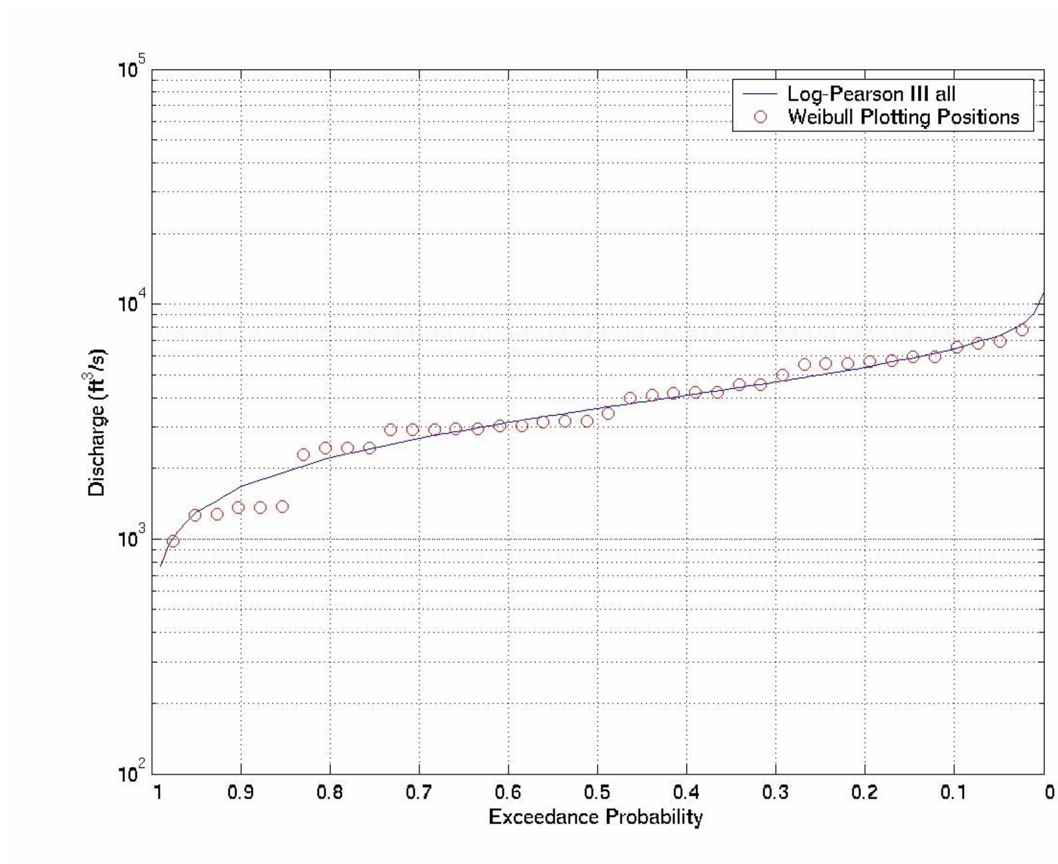

Figure H-2.23 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Acacia, New Mexico 08354900 for planning model alternative baseline.

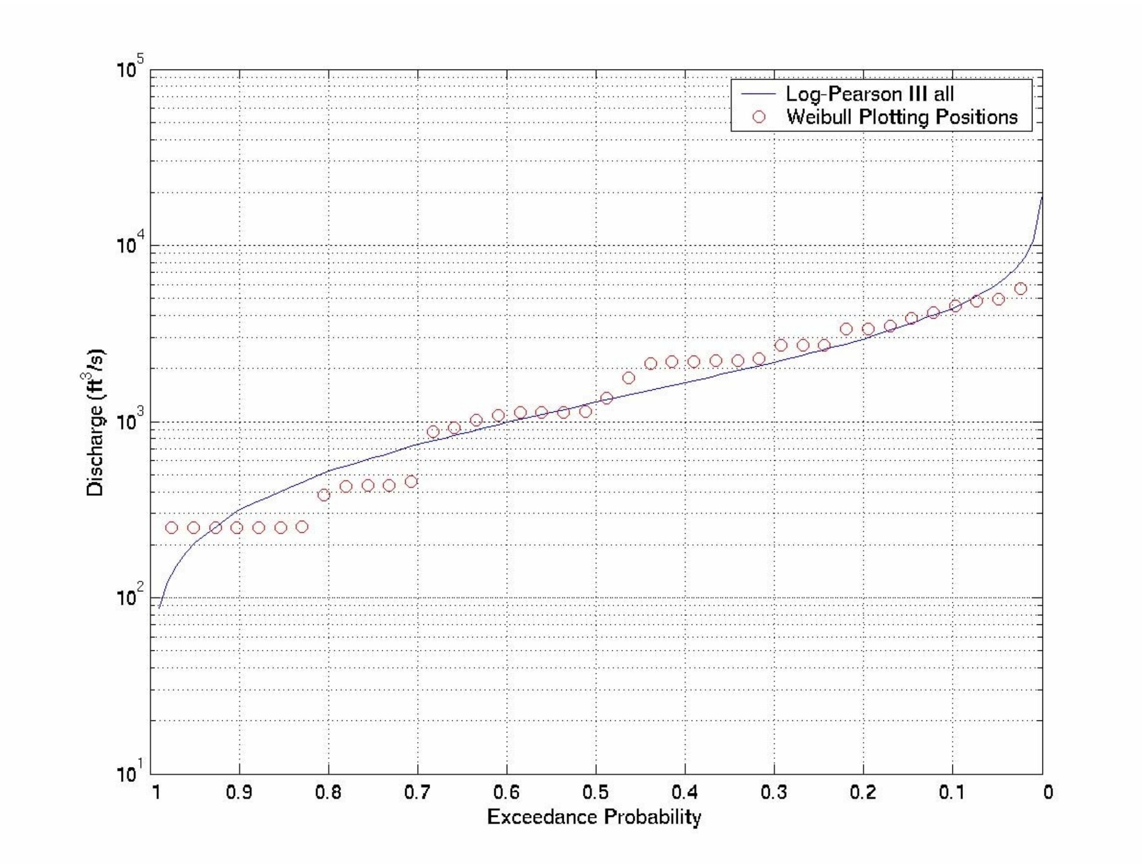

Figure H-2.24 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Acacia, New Mexico 08354900 for planning model alternative D3.

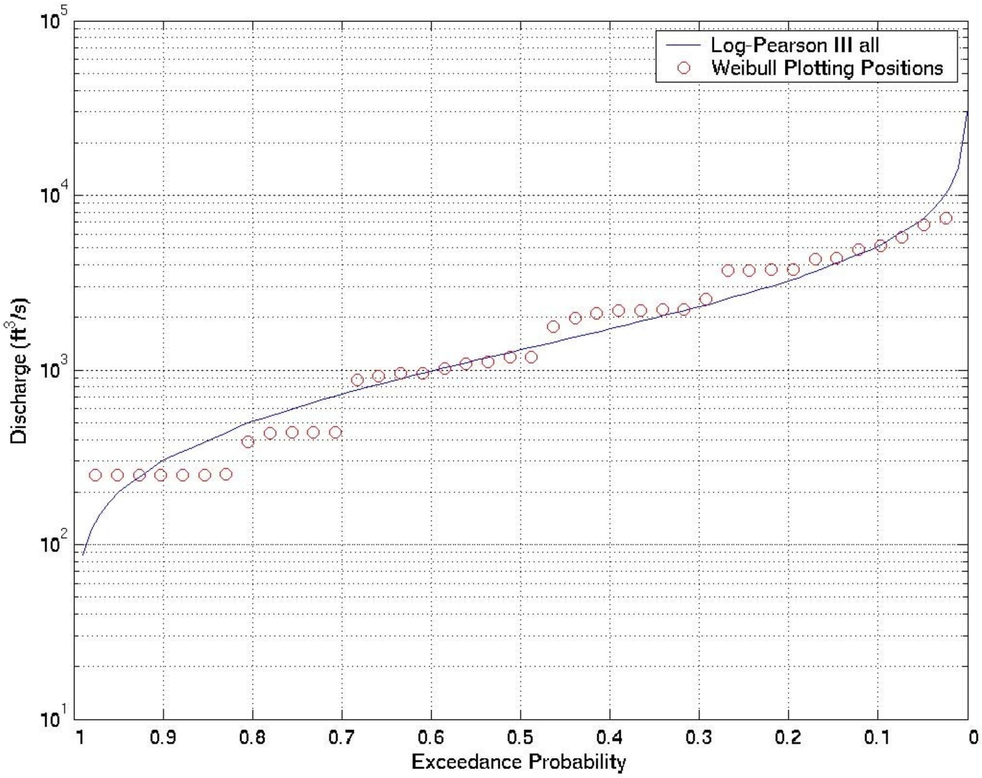

Figure H-2.25 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Acacia, New Mexico 08354900 for planning model alternative E3.

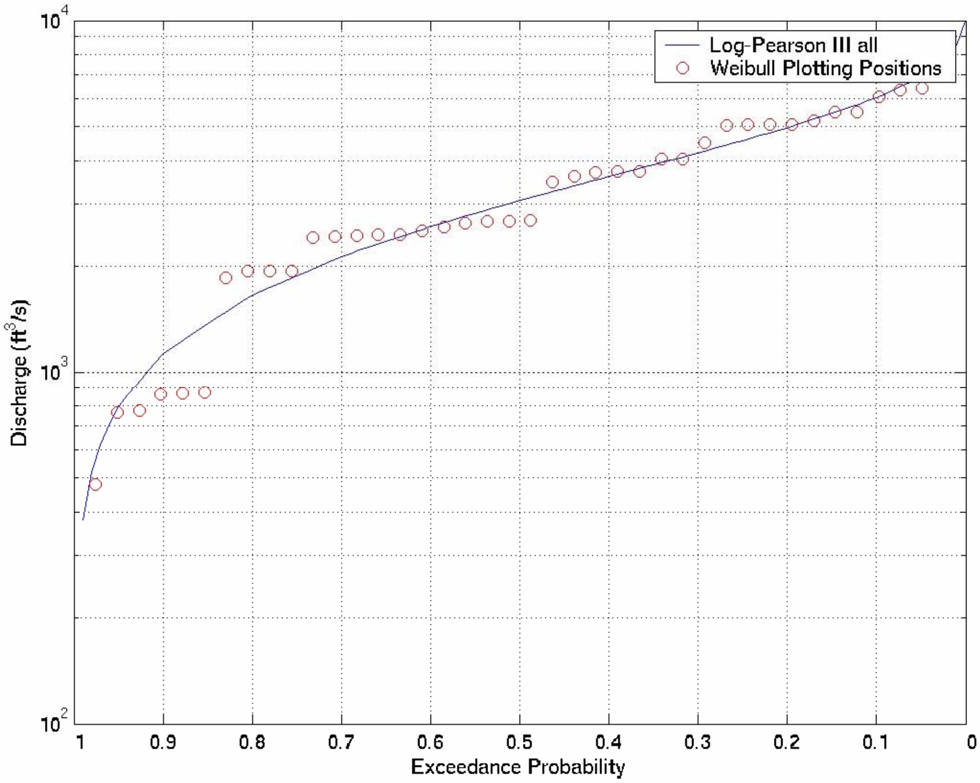

Figure H-2.26 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Acacia, New Mexico 08354900 for planning model alternative I1.

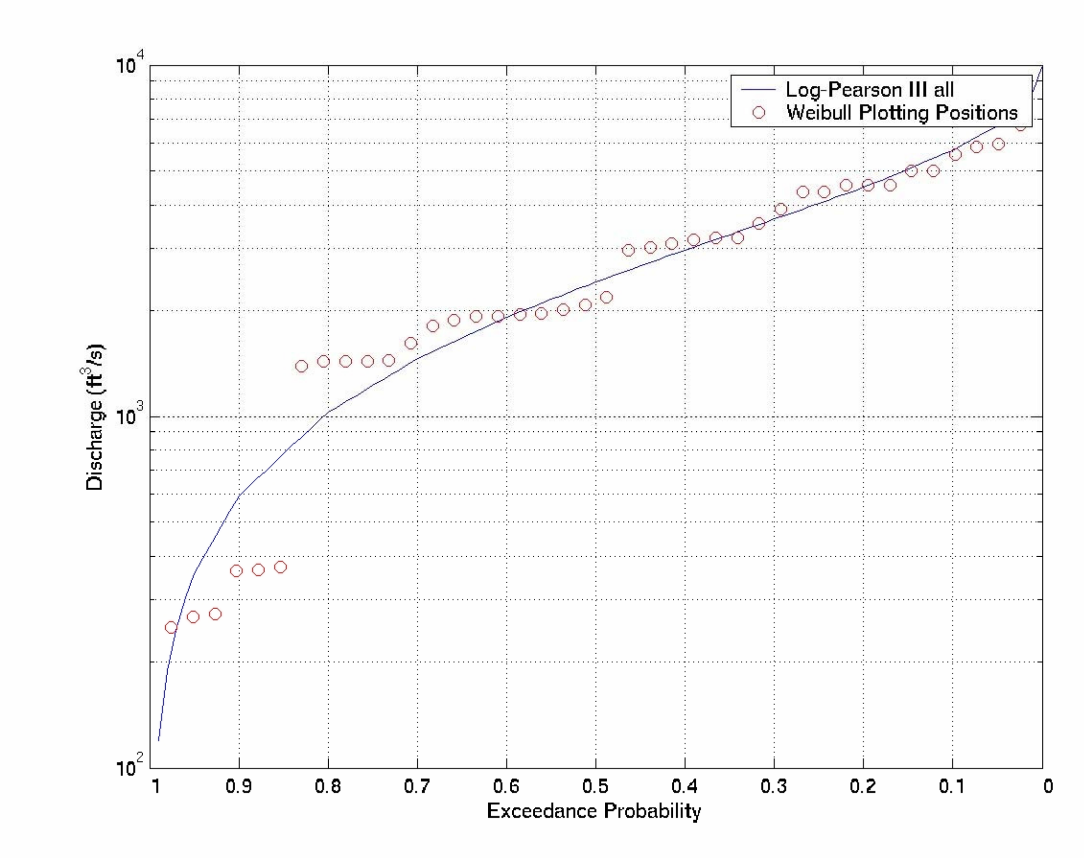

Figure H-2.27 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Acacia, New Mexico 08354900 for planning model alternative I2.

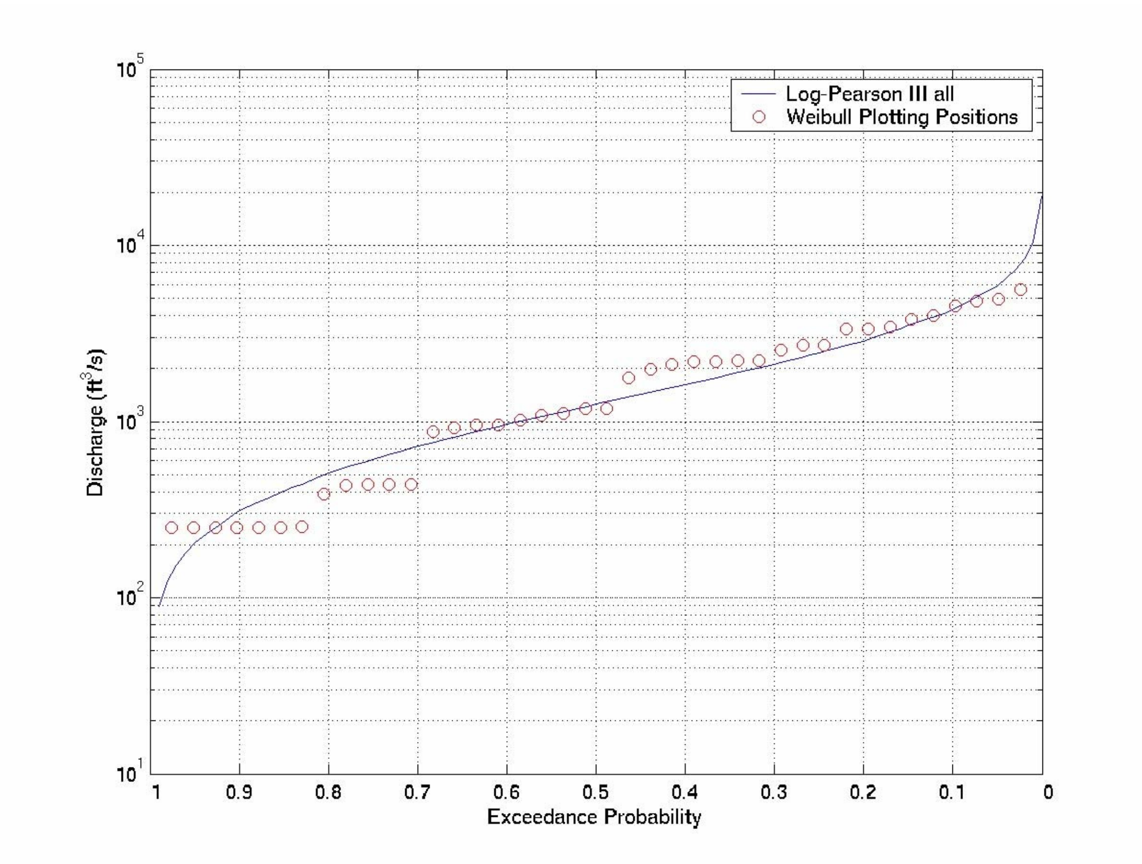

Figure H-2.28 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Acacia, New Mexico 08354900 for planning model alternative I3.

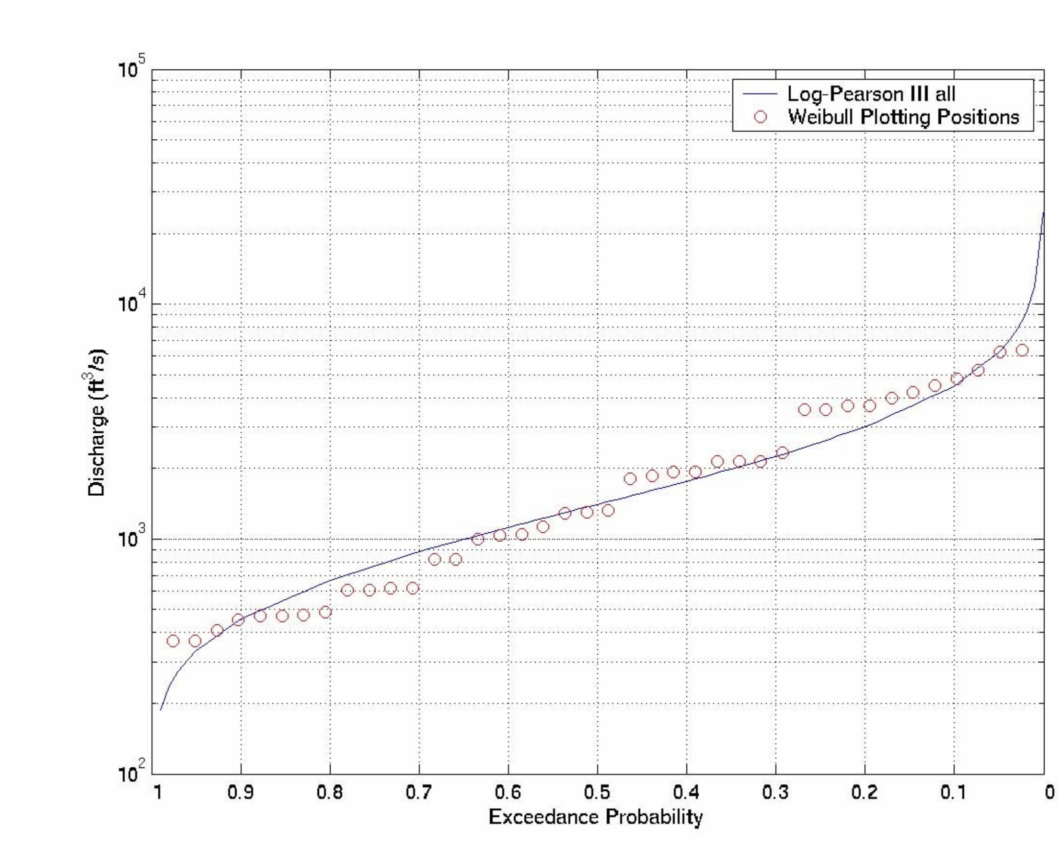

Figure H-2.29 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Marcial, New Mexico 08358400 for planning model alternative B3.

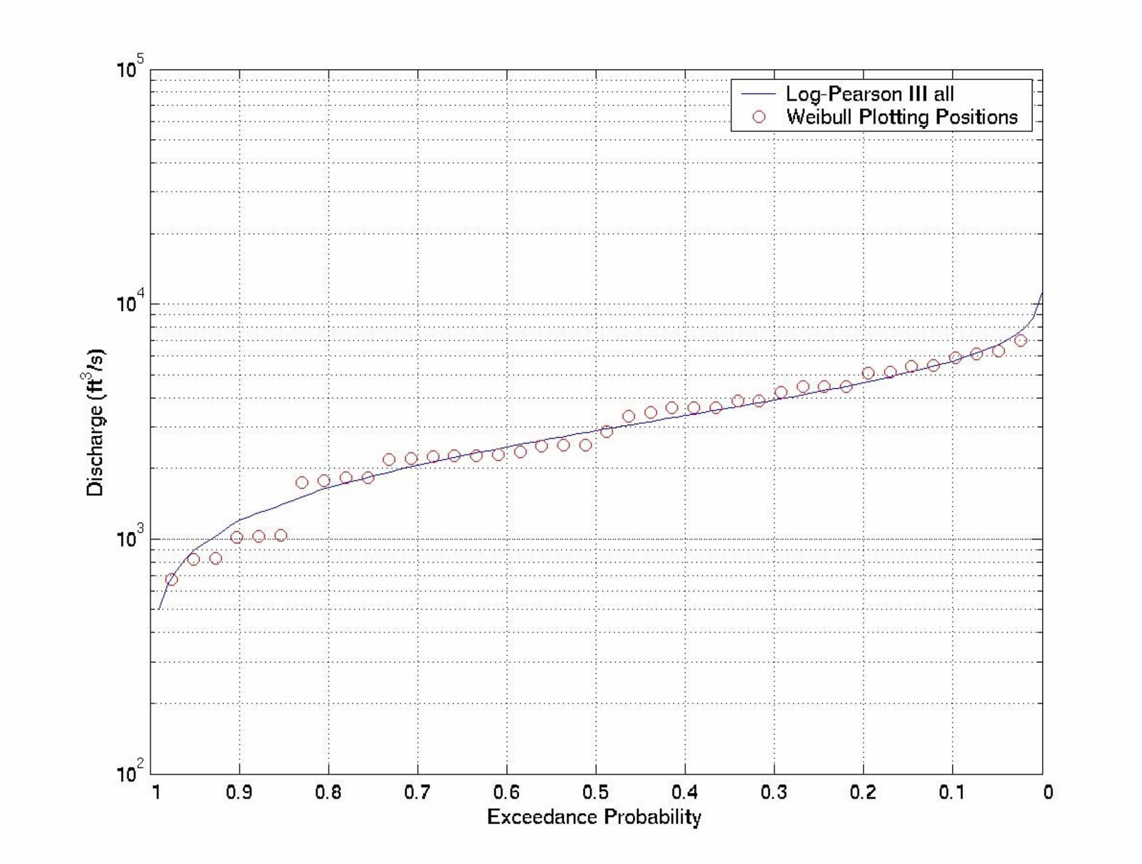

Figure H-2.30 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Marcial, New Mexico 08358400 for planning model alternative baseline.

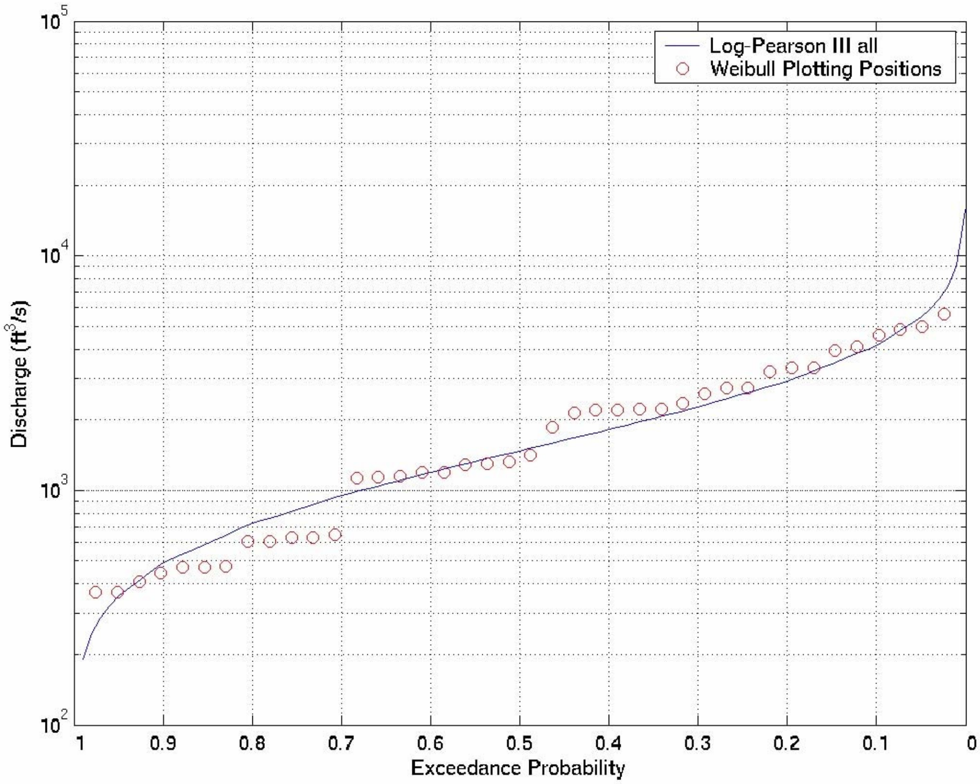

Figure H-2.31 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Marcial, New Mexico 08358400 for planning model alternative D3.

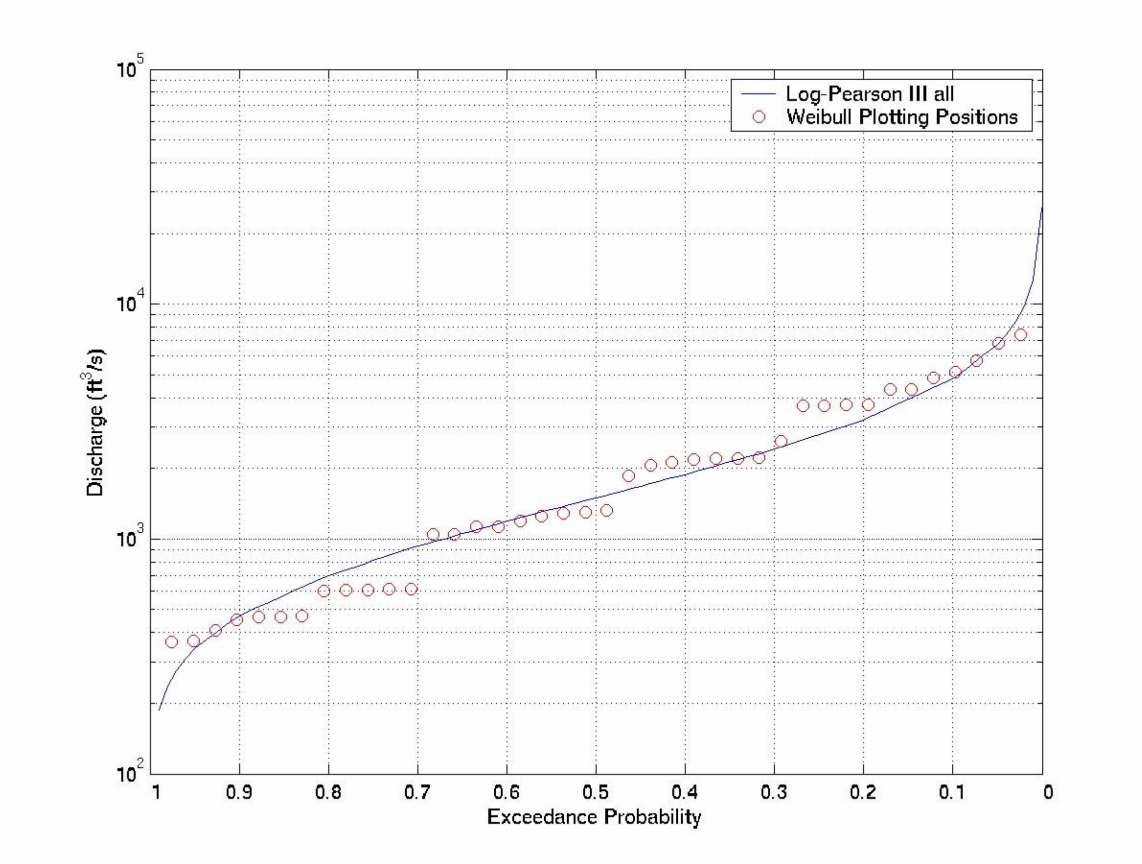

Figure H-2.32 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Marcial, New Mexico 08358400 for planning model alternative E3.

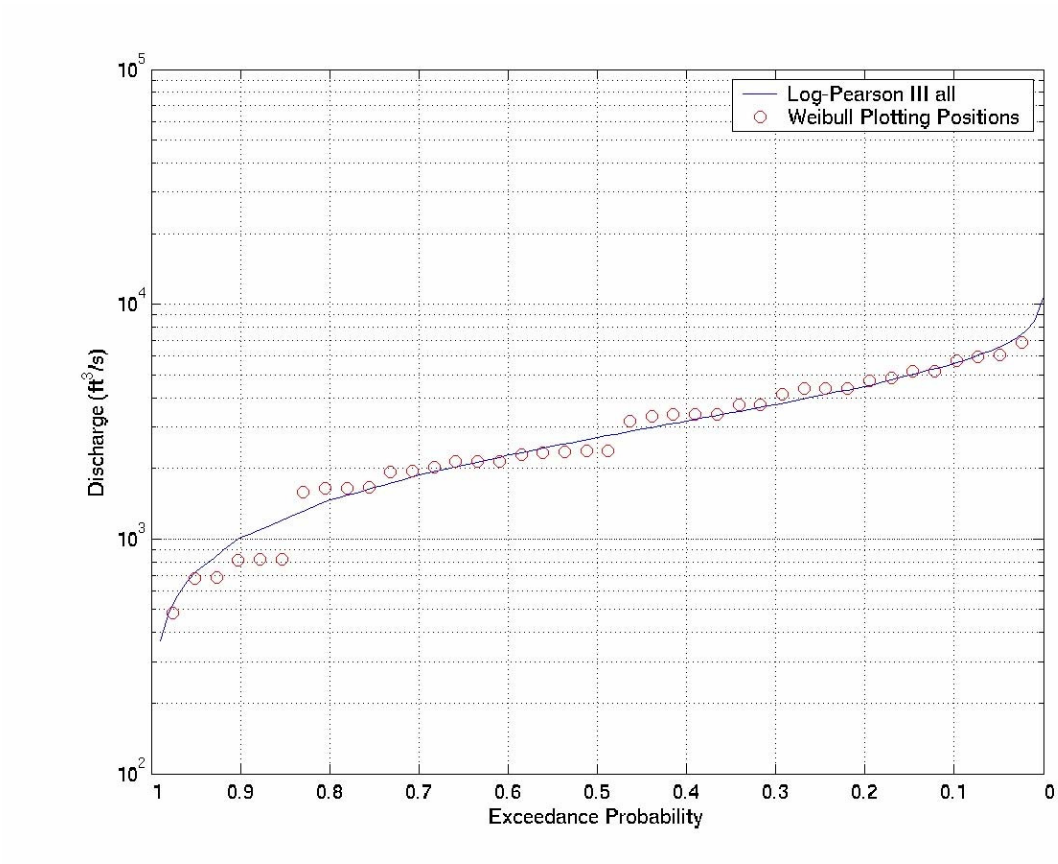

Figure H-2.33 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Marcial, New Mexico 08358400 for planning model alternative I1.

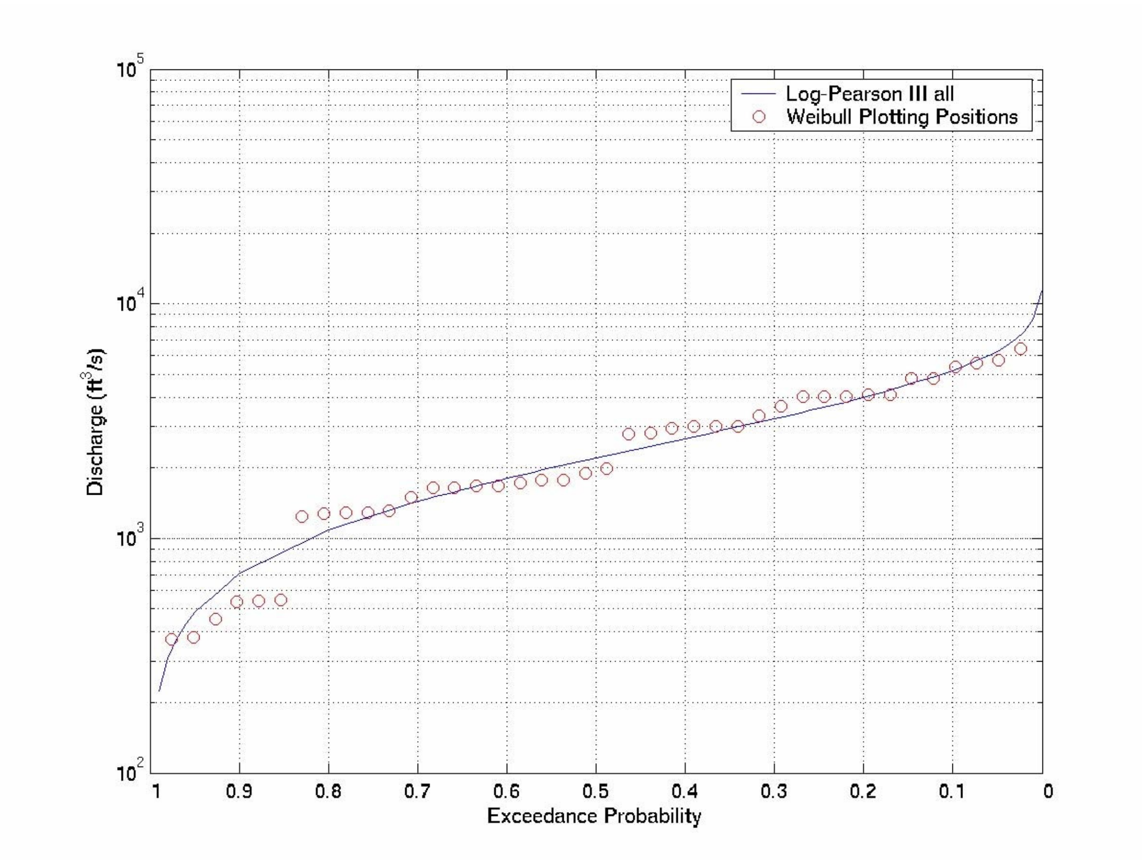

Figure H-2.34 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Marcial, New Mexico 08358400 for planning model alternative I2.

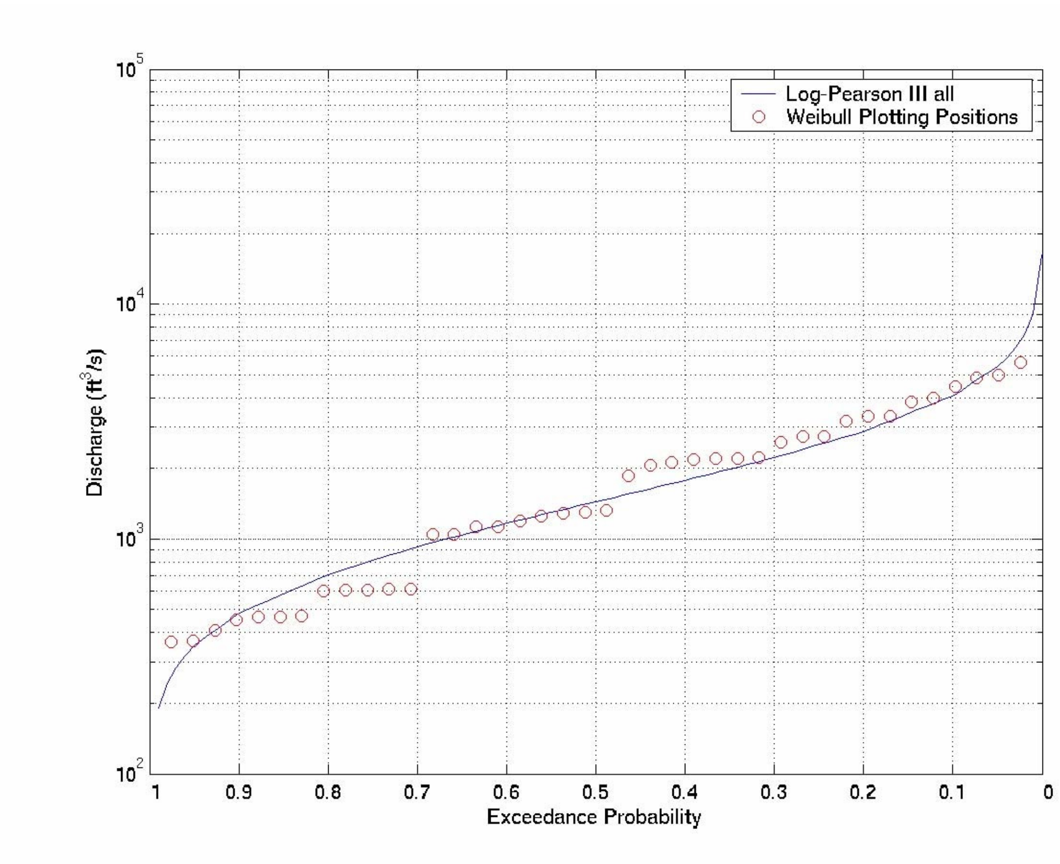

Figure H-2.35 Annual maximum daily mean discharge frequency curve at Rio Grande Floodway at San Marcial, New Mexico 08358400 for planning model alternative I3.

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3.0 UPPER RIO GRANDE WATER OPERATIONS EIS MIDDLE RIO GRANDE PLANFORM

Characterization and Analysis

Report Prepared by:

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June 2004

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center, Denver, Colorado

PEER REVIEW DOCUMENTATION

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Team Leader: Paula W. Makar

Water Resources Division Chief: Jim Pierce

Document Author(s)/Preparer(s): Paula W. Makar, P.E., Travis R. Bauer, P.E.

Peer Reviewer: Drew C. Baird; Ph.D, P.E.

Review Certification

Peer Reviewer: I have reviewed the document listed above and believe it to be in accordance with project requirements, standards of the profession and Reclamation policy.

Reviewer ______________________ Date reviewed ____________

Preparer: I have discussed the document listed above, review requirements, and believe that this review is completed, and the document will meet the requirements of the project.

Team Member ______________________ Date signed ____________

Team Member ______________________ Date signed ____________

DEPARTMENT OF THE INTERIOR MISSION STATEMENT

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitment to island communities.

BUREAU OF RECLAMATION MISSION STATMENT

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public

3.1 Introduction and Background

In support of the Upper Rio Grande Water Operations, Environmental Impact Study, an assessment of the river channel and floodplain morphology is presented for the Middle Rio Grande valley (**Figure H-3.1**) between the U.S. Army Corps of Engineers Cochiti Dam and the U.S. Bureau of Reclamation Elephant Butte Reservoir.

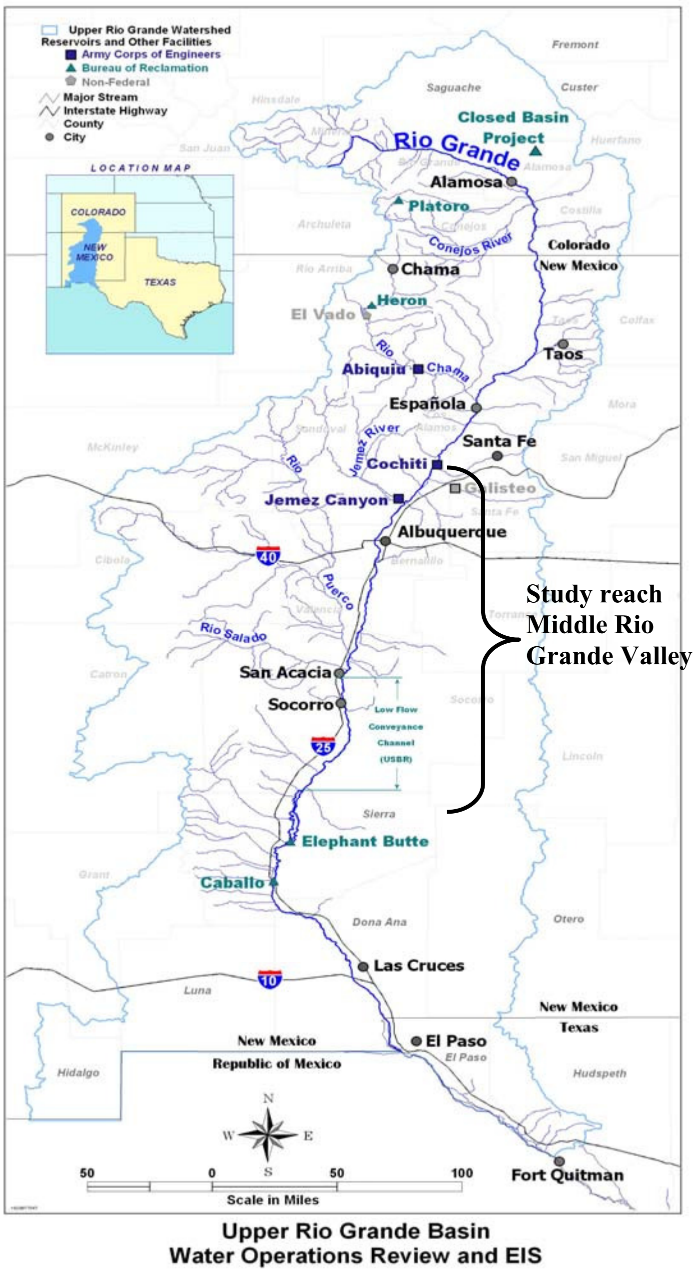


Figure H-3.1 Upper Rio Grande basin and study reach

This study describes the temporal and spatial distribution of the river planform characteristics of channel width, floodplain width, and island area. The knowledge gained through this characterization will be useful in decisions concerning future management of water operations because it documents natural and anthropogenic stresses to the system and the associated planform.

The Upper Rio Grande is an alluvial channel located primarily in the semi-arid state of New Mexico. The Upper Rio Grande Basin originates in the San Juan Mountains in southwestern Colorado. The Rio Grande passes through the San Luis valley and Alamosa, Colorado. Near the New Mexico border the Rio Conejos also joins the Rio Grande, which drains in a southeasterly direction. In northern New Mexico near the community of Espanola the Rio Chama joins the Rio Grande. Graf (1994) noted that the Rio Grande above Espanola yields more water and the Rio Chama produces more sediment. In the Middle Rio Grande valley, the Rio Grande encounters other tributaries that are ephemeral sediment producers such as the Rio Puerco and the Rio Salado. Below Elephant Butte Dam down to the terminus of the basin at Ft. Quitman, Texas, smaller flashy arroyos exist which mainly contribute sediment to the river channel.

3.2 River Morphological Influences

The flow regime of the Rio Grande has varied over time. There are two primary sources of change, climate and humans. Periods of extended drought or wet hydrology have in particular influenced the magnitude, duration, and frequency of channel forming flows and the river morphology. Based on the period of record for the Otowi Gage (representing inflow into Cochiti reservoir), hydrologically wet periods were experienced in the years 1927 – 1942 and 1972 – 1995 with dry periods occurring in 1924 – 1926 and 1943 – 1971. Another dry period began in 1996.

In the Upper Rio Grande Basin, anthropogenic influences to instream flows include: irrigation diversions and structures, water storage reservoirs, trans-mountain diversions, groundwater withdrawal, flood control dams and facilities, riverside water conveyance canals and drains, river channelization and grade control facilities. The major federal water delivery and flood control facilities include the following facilities with their corresponding year of establishment listed in downstream order: Alamosa Closed Basin groundwater wells and delivery canal (1980); Platoro Dam (1951); Heron Dam (1971); El Vado Dam (1935); Abiquiu Dam (1963); Cochiti Dam (1973); Galisteo Dam (1970); Jemez Canyon Dam (1953); the Low Flow Conveyance Channel (1959); Elephant Butte Dam (1916); and Caballo Dam (1938) as shown in **Figure H-3.2**. These water delivery and flood control facilities have altered the magnitude, duration, and frequency of instream flows.

Large floods are modified through reduced peaks and delayed releases. Reduced peaks are illustrated by the comparison of the flood of 1941 with 22,000 ft^3/s at Otowi Bridge and 22,400 ft^3/s downstream of the Cochiti Dam site to the 1985 flood of 12,000 ft^3/s at Otowi Bridge and 8,290 ft^3/s downstream of Cochiti Dam. These floods occurred during hydrologically wet periods, but the second flood is reduced below Cochiti by nearly one third. Peak releases from Cochiti are less than 7,000 ft^3/s during the current dry period but average only 3500 ft^3/s.

The general effect of current river operations on the Middle Rio Grande morphology has been that peak flows have decreased in magnitude leading to a decrease in the river channel width (**Figure H-3.3**). This decrease in width is also due in part to vegetation encroachment in the channel that may have been exacerbated by the reduction in peak flows and drought and the cessation of vegetation clearing in the Floodway (**Figure H-3.4**). Note the open sandy channel in 1992 and the increase in vegetated islands and attached bars by 2002. The river channelization work during the 1950s and 1960s of straightening and jetty jack installation is another major factor in width reduction. The jetty jacks were installed to create a channel width of 550 – 600 feet, designed to more efficiently convey water and sediment.

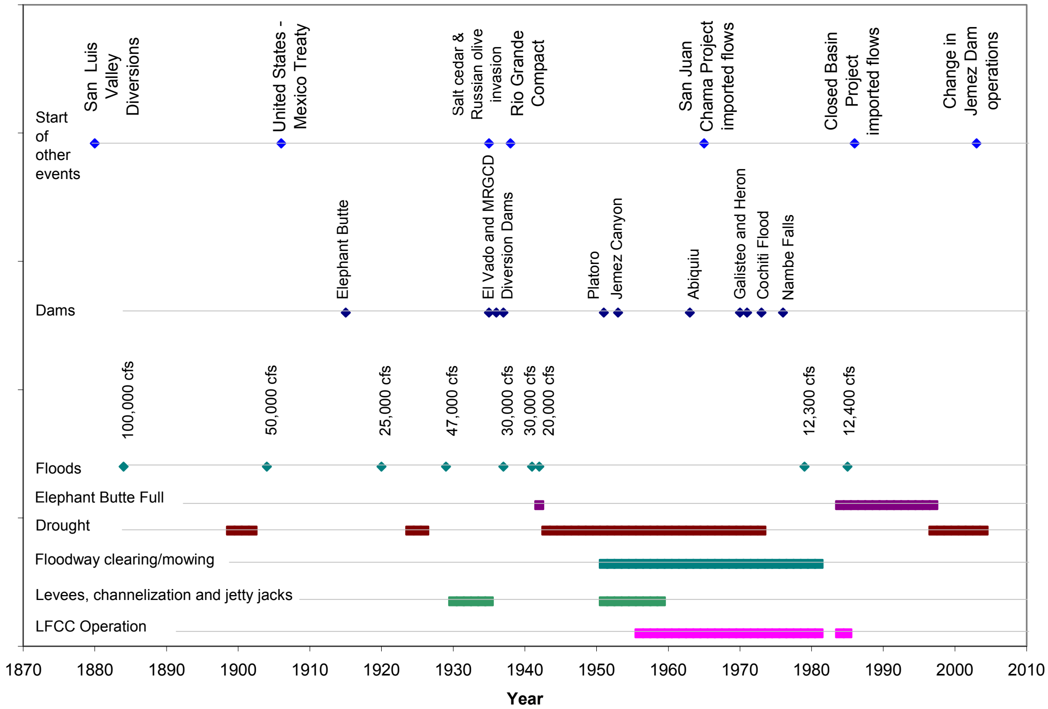


Figure H-3.2 Timeline of significant events

The sediment supplied to the Middle Rio Grande has also changed significantly over time. The sources of change are similar to that of the flow regime, the establishment of major federal water delivery and flood control facilities and climate changes. Facilities such as Cochiti Dam, Galisteo Dam, and Jemez Canyon Dam have generally captured a significant portion of the sediment. The Kelner jetty fields also caused sediment deposition and storage allowing vegetation colonization which narrowed the river channel and increased the sediment transport capacity.

Climactic influences generally apply on larger, regional basis. Hereford (2002) postulates that the episodic increase of the frequency of large floods in the late 1800s resulted in historic arroyo cutting and a large increase in sediment supply to the river. Subsequent aggradation occurred during a period of infrequent large floods. These patterns are probably related to the El Nino-Southern Oscillation and its effects on atmospheric and oceanic circulation.

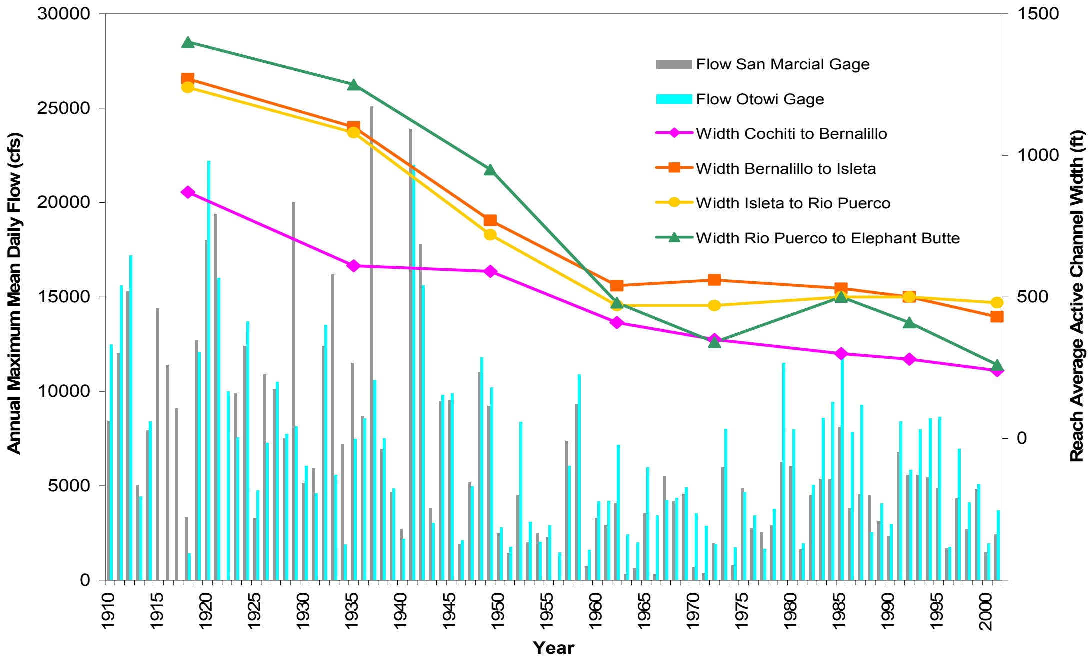


Figure H-3.3 Comparison of peak flow and reach average width

Figure H-3.4 Vegetation encroachment inside channel margins between 1992 and 2002

In the Upper Rio Grande basin, physical processes that influence the river morphology are dependent on the basin hydrology, river hydraulics, sediment supply and transport, riverbed topography, bed sediment size, and vegetation. When one or more of these change, the river may respond with a change in morphology. The direction of a channel's response is easier to ascertain than the magnitude or rate. The simplest description of the relationship between water and sediment is Lane's equation (Lane 1955)

$$Q_s\, d \propto Q_w\, S$$

Where

- Q_s= sediment load (of sizes represented in the riverbed),
- d= sediment particle diameter of the riverbed,
- Q_w= water discharge, and
- S= river channel slope.

In other words, $Q_s d$ is proportional to $Q_w S$. For example, the discharge released from a reservoir is usually clear water (low in sediment) and Lane's relationship implies the downstream channel slope will flatten to reduce the stream's energy and the sediment transport capacity. The size of sediment particles may control the extent of degradation. If the channel becomes armored such that the discharge cannot transport the larger particles; the sediment transport capacity may still be unmet from bed degradation alone. The sediment transport capacity may also be at least partially met by bank erosion and lateral migration, a process not described by the Lane relationship.

This assessment does not directly describe the individual effects of various anthropogenic, geologic, hydrologic, and climatic influences on the river's morphology. Given the broad scope of these influences to the river's morphology, such an endeavor would be difficult to accomplish within the scope of this characterization and assessment. Therefore, a qualitative discussion of the cause and effect relationships between natural/anthropogenic influences and river's planform morphology and pattern are presented.

3.3 River Operations Reaches

The study reach has been sub-divided, as shown in **Table 3-1** and **Figure 3-5**, into four reach designations representing river channel areas that share similar processes. Two dams, a change in planform/bed material, a tributary confluence, and a reservoir boundary serve as physical landmarks for the reach boundaries. The planform/bed material change is at Bernalillo, which was the southernmost point where the river bed was a single thread, coarser bed channel when the study began. This point has migrated downstream and in 2004 is near Rio Rancho/Corrales.

The Middle Rio Grande Aggradation/Degradation (agg/deg) rangelines (Abram, 1962) are also used to identify the reaches. The rangelines are historical cross sections established in the study reach to monitor the morphologic condition of the river channel. These rangelines, established in 1962, include the channel and floodplain and are spaced at approximately 500 foot increments along the river. The agg/deg rangeline locations are generally perpendicular to the river. The final column in **Table 3-1** contains the corresponding river miles (from the 1972 alignment) where Caballo Dam is river mile zero and miles increase in the upstream direction.

Table H-3.1 River Operations reaches

Reach	Name	Agg/Deg Lines	River Miles
Cochiti Dam to US 550 at Bernalillo	COBL	19-298	233-204
US 550 at Bernalillo to Isleta Diversion Dam	BLIS	298-655	204-169
Isleta Diversion Dam to Rio Puerco Confluence	ISRP	655-1099	169-127
Mouth of Rio Puerco to Elephant Butte Reservoir	RPEB	1099-1790	127-61

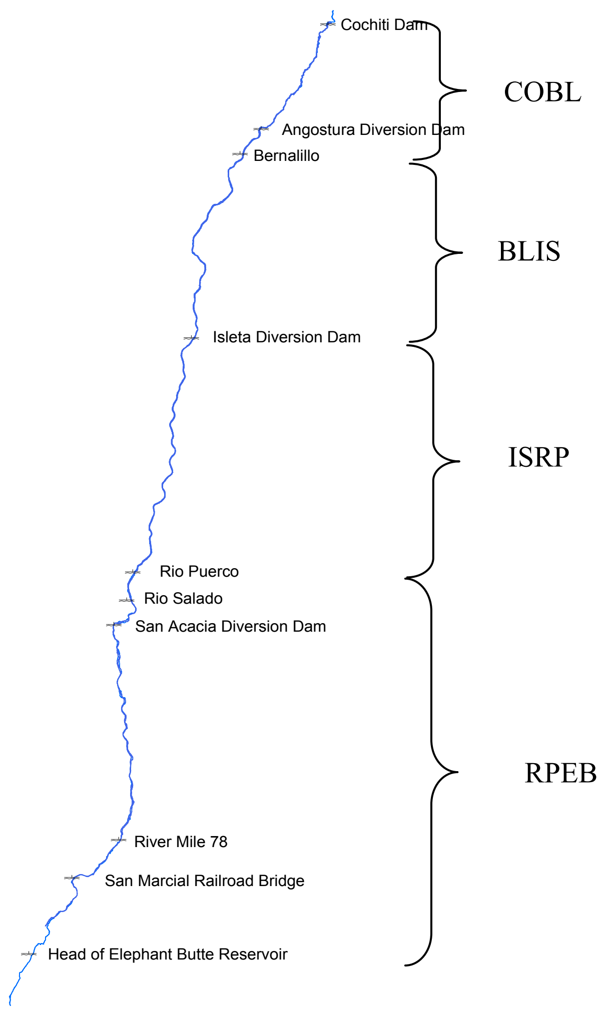


Figure H-3.5 River Operations reaches

The most upstream reach is between Cochiti Dam and the US 550 (NM 44) Bridge in Bernalillo (COBL). Moving downstream, the next reach is from Bernalillo to Isleta Diversion Dam (BLIS). Next is the reach from Isleta Diversion Dam to the mouth of the Rio Puerco (ISRP). The last reach runs from the mouth of the Rio Puerco to Elephant Butte Reservoir (RPEB). Differences in river processes described in Makar and Strand (2002), Massong et. al. (2001), and Richard et. al. (2001) indicate that additional subreach divisions at San Acacia Diversion dam and near rivermile 78 may also be useful.

Agg/deg rangeline 1790 (River mile 61) was selected as the endpoint for this study for several reasons. First, the 1935 data ends there. This rangeline is near the conveyance channel outfall at station 1800 and is also near the full reservoir pool boundary. During the dry period of the 1940s through the 1970s, the head of the reservoir receded to the Narrows of Elephant Butte reservoir (downstream of agg/deg 1962). The head of the reservoir is currently (2003) below the Narrows. During periods of lower pool elevation, the floodway between agg/deg 1790 and the reservoir pool becomes more riverine in character, to a large extent due to mechanical efforts to maintain a viable channel to the reservoir.

3.4 Methods

Reach average values for the channel width, floodplain width, island area, and sinuosity were calculated from digitized information in the Rio Grande GIS database (Oliver 2004). These variables are used to quantify changes in the planform river morphology both temporally and spatially. Channel widths for individual agg/deg lines are used to assess changes in variability.

3.4.1 GIS Database

Planform data in the form of maps and aerial photographs are available in the GIS database for eight data sets during the time period 1908 to 2001 (**Figure H-3.2**). **Figure H-3.6** is an example of the digitized morphology. The materials used to create the GIS database used in this study were Middle Rio Grande Project mapsheets, black and white aerial photography, tabular data and graphs, and hand-drafted linens obtained from the Albuquerque Area Office of the United States Bureau of Reclamation. The scale of the image-based source material varies and is 1:4800 for 1949, 1962, 1972, 1984/1985, 1992 and 2001. The 1949 images are photo-mosaics, the 1962, 1972, and 2001 images are ratio-rectified photo-mosaics and the 1984/1985 and 1992 images are ortho-photos. The Rio Grande upstream of Belen was photographed in 1984 and downstream in 1985 by two different companies. The scale of the enlarged photo-mosaics for 1935 is about 1:8000. Mapsheet scale estimations were derived from the ratio of the distance between two points which could be located on both the 1935 photo-mosaic and the 1992 ortho-photo mapsheet. The scale of the 1918 maps drawn on linen is 1:12000. All aerial photography is black and white. The orthophotos and photo-mosaics are printed on mylar except 1949, which are on acetate film, and the 1935/1936 mosaics which are on photographic paper. The 1918 data ends downstream of San Marcial, but a 1908 map, at a smaller scale, shows a river channel through Truth or Consequences. Because this is a short, very narrow section of valley and channel, the two data sets were combined for this analysis. Metadata (Oliver 2004) that accompanies this database documents the categories of data and the limitations and sources of the data in detail.

Figure H-3.6 Digitized Rio Grande 2001 morphology near Santo Domingo, NM

3.4.2 Geomorphic categories

Several categories in the GIS database are neither immediately intuitive nor simple. For ease of reference, brief definitions of the categories are as follows:

- Active channel – area between the mature riparian vegetation bank line
- Arroyo – areas of intermittent tributaries that contribute sediment
- Floodway clearing - areas bordering the active channel that were mechanically cleared
- Historic channel - area once occupied by the active river channel
- Out of study area – areas outside of confining levees and terraces or mesa
- Ponded water – areas of standing water
- Recent change - areas cleared or abandoned by the river between years of photography
- Tributary – large, more frequently flowing tributaries
- Upland – areas of non riparian vegetation or agriculture
- Vegetated island – areas surrounded by channel with mature vegetation

Detailed discussions on specific categories pertinent to this study can be found in the following sections.

3.4.3 Active Channel Width

The digitized active channel was classified as the area between the mature vegetation riparian boundary lines on either river bank and includes sandy areas cleared of vegetation by the river. The channel areas labeled *sand* on the 1918 linens were assumed to be similar to the cleared sandy areas observed in the aerial photos and so digitized. Where possible, the areas bulldozed for floodway clearing activities were assigned to a separate category. It should be noted that where the 1918 and 1908 channels overlap, they are in the same location but **not** the same width and the 1918 width is used where available.

For this study, the active channel width is assumed equivalent to the riparian boundary and does not include vegetated islands. A reach-averaged value for active channel width was calculated two different ways. For the first method, the width of the active channel was summed along the agg/deg rangelines then divided by the number of the rangelines within a reach. The agg/deg lines are not always perpendicular to the channel or the flow path, resulting in a potential error in the channel widths for method 1. In the second method the area of the active channel between the reach defining agg/deg rangelines was calculated from the GIS database. This area was divided by the length of the centerline of the channel. The centerline was used because a low flow thalweg is generally much more sinuous than the centerline of the channel formed at high flows. Method 2 was used to calculate the reach averaged width values reported here. This method does not provide any information on the variability of widths within a reach, so method 1 is used in a separate analysis of channel width variability statistics.

3.4.4 Floodplain Width

The floodplain width reported is not based on hydraulic modeling of a specific discharge, but is a visual representation of the potential floodplain that was digitized from the 1935 photos. The floodplain area was edited from the GIS coverage to be the area between confining levees, when present, or up to the historical channel/upland boundary in the absence of levees. Adjustments were made to the coverage for changes in levees and bank erosion along the Rio Grande channel for the years 1949, 1962, and 1992. The 1918 geomorphology coverage includes only the active channel since the hand-drawn maps did not have enough information to delineate the floodplain. The 1962 coverage was compared to the 1992 coverage and little change was evident. It was assumed the 1972 and 1984/5 floodplain boundaries were not significantly different and therefore were reported. Little change was noted between 1992 and 2001 during digitizing, so 2001 floodplain boundaries were also not edited or reported. In some locations and years, the floodplain area was cut off at the edge of the map. This missing area varied among the different sets of data, and could change the value calculated for reach-averaged floodplain width. **Figure H-3.7** illustrates the cutoff near the Bosque del Apache National Wildlife Refuge (BDANWR).

The method used to define floodplain area was initially to combine the polygon categories of active channel, recent change, vegetated islands, floodway clearing, and historical channel and exclude upland areas. Areas under cultivation in the floodplain were digitized as upland under the assumption that these areas would be defended from flooding. For this analysis, agricultural clearings in the 1935 and 1949 riparian/historical channel/floodplain were edited to be included in the floodplain polygons unless the clearings were protected by levees. Where upland uses destroyed clear evidence of river activity, the area was categorized as upland in the database. Agricultural clearing was more abundant in the 1935 data but much of the clearing was abandoned after 1935. Riparian vegetation had reclaimed a good deal of the abandoned area by 1949 and so was included as part of the floodplain.

Confining levees were used as limits to the extent of the floodplain areas. Where levees didn't connect across arroyos or drains, a direct line closed the area with the closest confining feature because there was insufficient data to determine the extent of flooding up the arroyo. Generally, the area of these fans was determined to not be significant enough to warrant the time to edit them in the GIS floodplain coverages. An exception was the Rio Salado alluvial fan that was quite large in 1935 but diminished in size by 1949. The floodplain definition in the fan area was not altered from the direct line procedure described above because of the lack of elevation data.

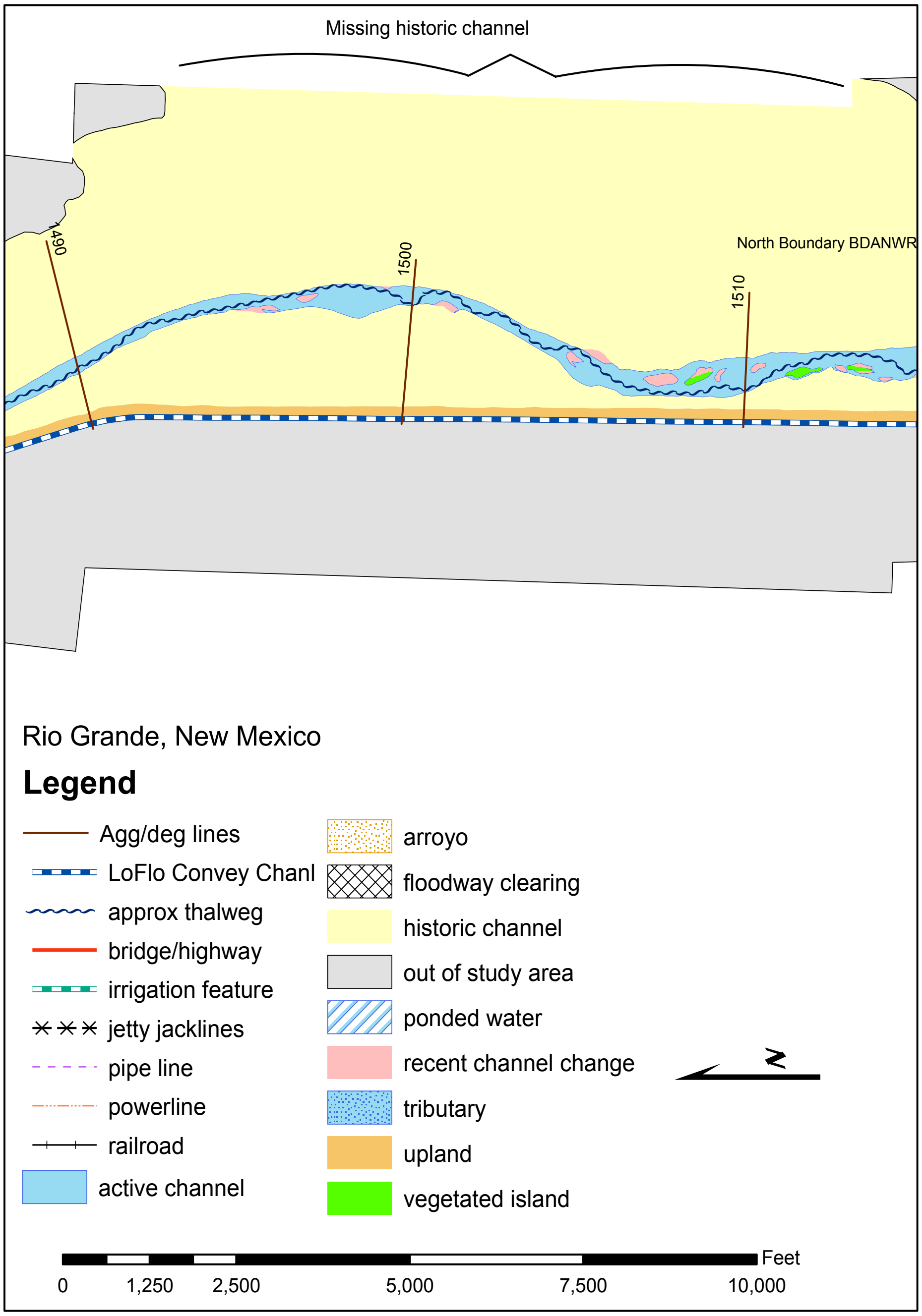


Figure H-3.7 Missing or cutoff historical channel near BDANWR

The 1935 photography did not always cover the entire floodplain, e.g. the east side of the Rio Grande in the area immediately above the Rio Salado. Where data was missing in 1935, the 1949 floodplain was used to complete the 1935 data for the purpose of these measurements. The same methodology was used in reverse for the area above San Acacia Diversion Dam where data was available for 1935 but not for 1949.

Floodplain width was calculated three ways. In the first two methods, the reach floodplain area, as defined above, was divided by length. The first method used channel centerline length and the second used valley length. Changes in valley length during different time periods are discussed section 4.5. For the third method, the floodplain width measurements were collected using an edited version of every 10th agg/deg line. The selected rangelines were extended and/or rotated, where required, such that they crossed the floodplain without intersecting adjacent agg/deg lines. Again, these rangelines were not always perpendicular to the channel or valley. The measured floodplain widths were then averaged within the defined reaches. The floodplain area divided by valley length was then used for width calculation in this study (method 2) for consistent trend comparison with the active channel widths. Widths are reported to the nearest 50 feet due to the data issues discussed above.

3.4.5 Island Area

The current Rio Grande GIS classification of a vegetated island describes areas of vegetation exceeding several seasons of growth separated from the historical channel by active channel, and in some instances, surrounded by a combination of active channel and recent change in the active channel. This definition evolved when the Cochiti Dam to San Acacia Diversion Dam reaches were digitized as discussed below.

Digitizing of islands began in the San Acacia Diversion Dam to Elephant Butte area. Originally, a vegetated island was defined as vegetation surrounded by active channel. In some cases, an abandoned channel might cause an isolated area of vegetation to be separated from the historical channel by an area of recent change. The sparsely vegetated or rocky debris was not active channel, so in this scenario the isolated mature vegetation continued to be classified as historical channel rather than as an island.

When digitizing the Cochiti Dam to San Acacia Diversion Dam area, there was not always a clear distinction between an abandoned channel versus a new channel developing. Identification of an island developing as a result of a new channel was not always clear. The classification definitions were broadened to reduce the number of categories. This change proved useful when identifying where the jetty jack lines changed the flow path or where pilot channels were cut through the historical channel because of the uncertainty in channel identification as discussed above.

As a result of the broadened island classification, island area data for all reaches included both “isolated historical channel” and “islands attached to the historical channel by recent change.” Both of these areas were further identified as “attached.” The reach-averaged island areas, with and without attached islands, were compared. There was little difference between the results except downstream of San Acacia from 1962 and later because of the change in island identification. To ensure a consistent interpretation for the entire study, the island areas with “attached” data are reported.

3.4.6 Sinuosity

Sinuosity is defined as the length of the channel divided by the valley length. In the GIS database, two channel lengths were available - the length of the channel centerline and the length of the thalweg. The thalweg length is more appropriate for analysis of low flows and results in a higher calculated sinuosity. The length of the channel centerline is more pertinent to bankfull discharge. Other data in this study are dependent on bankfull discharge so sinuosity based on channel centerline is reported. Valley length is the shortest distance the river could travel measured down the valley. This length is modified in some areas due to levees or other structures that limit river movement. For example, downstream of San Acacia Diversion Dam the Low Flow Conveyance Channel (LFCC) levee limits the area available for channel movement and thereby extends the valley length, as shown in **Figure H-3.8**.

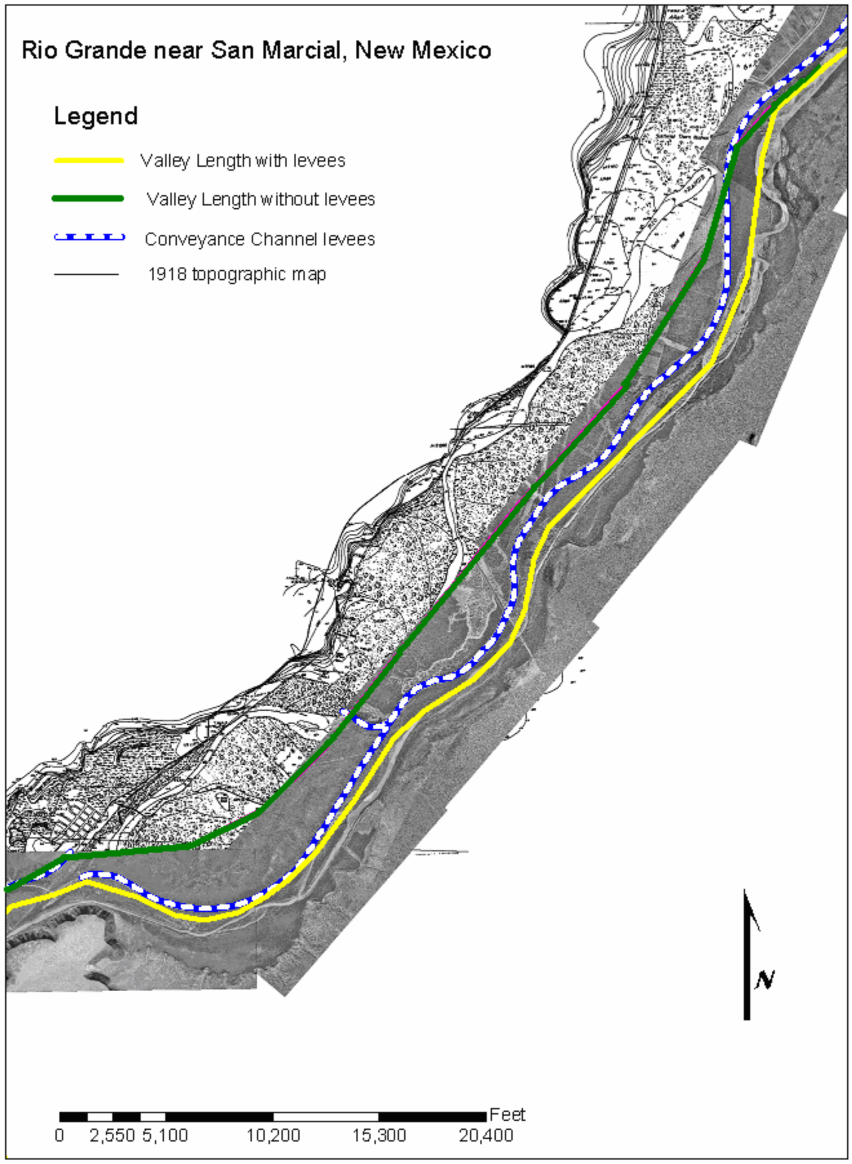


Figure H-3.8 Comparison of valley length with and without LFCC levee.

3.5 Results and Discussion

Mean values of width, floodplain width, island area and sinuosity changes are presented to facilitate comparison of these variables by reach over time.

3.5.1 Active Channel Width

Table H-3.2 and **Figure H-3.9** present the reach-averaged active channel widths by year. **Table H-3.3** presents the total and yearly percentage change between datasets.

Two trends are apparent. Width generally decreases over time through 1962. Much less change is noted from 1962 to 1992, due in part to channel maintenance. The change in hydrology from a dry period to a wet period with greater discharges is likely the source of the increases noted from 1972 to 1984/5 in the

ISRP and RPEB subreaches. The narrowing seen in 2001 is in most cases the result of island and bar formation during a period of low flow. The persistence of these channel features will be a function of the size of future flows and vegetation growth.

Table H-3.2 Reach-averaged active channel widths (feet)

Year	COBL	BLIS	ISRP	RPEB
1918	870	1270	1240	1400
1935	610	1100	1080	1250
1949	590	770	720	950
1962	410	540	470	480
1972	350	560	470	340
1984/5	300	530	500	500
1992	280	500	500	410
2001	240	430	480	260

Table H-3.3 Percent change from previous data set in reach active channel widths

		COBL		BLIS		ISRP		RPEB	
Year	Years between data sets	Total change (%)	Change per year (%)	Total change (%)	Change per year (%)	Total change (%)	Change per year (%)	Total change (%)	Change per year (%)
1935	17	-30	-2	-14	-1	-13	-1	-11	-1
1949	14	-4	0	-30	-2	-34	-2	-24	-2
1962	13	-30	-2	-30	-2	-35	-3	-50	-4
1972	10	-14	-1	4	0	0	0	-30	-3
1984/5	12/13	-14	-1	-5	0	8	1	48	4
1992	7/8	-7	-1	-5	-1	0	0	-18	-3
2001	9	-13	-1	-14	-2	-5	-1	-35	-4

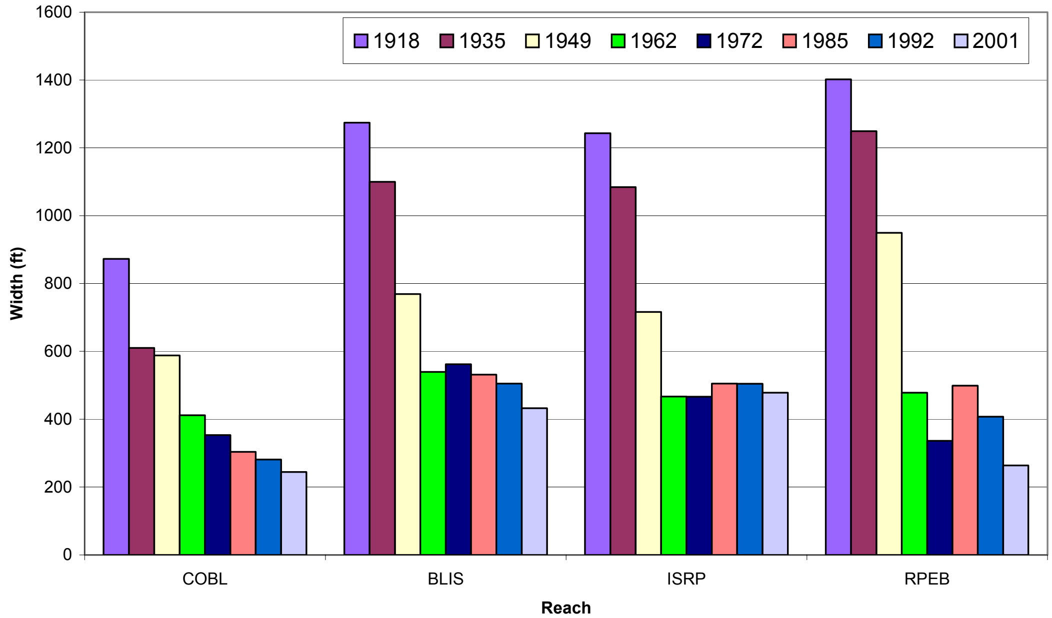


Figure H-3.9 Reach-averaged active channel width over time

3.5.2 Floodplain width

Floodplain widths follow a similar pattern of significant decrease between 1949 and 1962 as shown in **Table H-3.4** and **Table H-3.5** and **Figure H-3.10**. Again, no interpretation of floodplain data was possible from the 1918 linens. The large decrease in RPEB from 1949 to 1962 is due to the floodplain cutoff by the LFCC construction. The general increase from 1935 to 1949 is attributed to cases where land cleared in the 1935 photos could not be positively identified as floodplain and then showed up as riparian vegetation in 1949 (see floodplain width discussion in section 4). Little difference in floodplain widths was seen between 1962 and 1992 except for the reduction due to the Drain Unit 7 extension near the Rio Puerco, so data for 1972 and 1985 were not calculated. It has also been assumed that the lack of change extends into 2001.

Table H-3.4 Reach-averaged floodplain widths (feet)

Year	COBL	BLIS	ISRP	RPEB
1935	2000	1900	2250	4300
1949	2400	1950	2400	4300
1962	2000	1800	2050	2500
1992	2000	1800	2050	2450

Table H-3.5 Percent change from previous data set in reach floodplain widths

		COBL		BLIS		ISRP		RPEB	
Year	Years between data sets	Total change (%)	Change per year (%)	Total change (%)	Change per year (%)	Total change (%)	Change per year (%)	Total change (%)	Change per year (%)
1949	14	20	1	3	0	7	0	0	0
1962	13	-17	-1	-8	-1	-15	-1	-42	-3
1992	20	0	0	0	0	0	0	-2	0

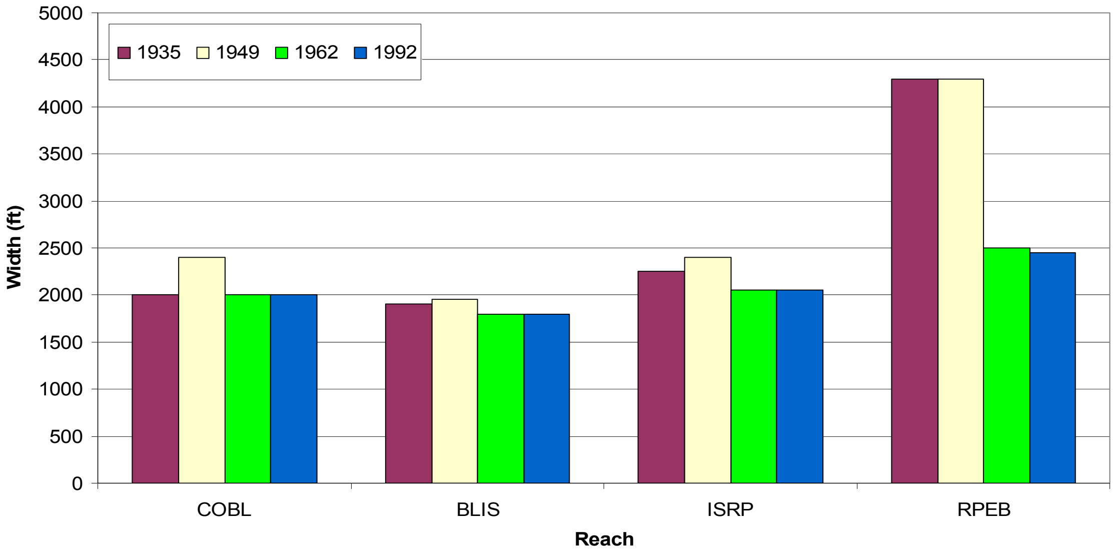


Figure H-3.10 Reach-averaged floodplain widths over time

3.5.3 Island area

Island area trends over time were much less consistent than either active channel or floodplain widths. **Table H-3.6**, **Table H-3.7** and **Figure H-3.11** show this complexity.

Table H-3.6 Reach island area (acres)

Year	COBL	BLIS	ISRP	RPEB
1918	2060	490	650	430
1935	440	360	870	540
1949	620	250	340	130
1962	440	170	90	430
1972	220	50	30	350
1984/5	150	40	0	210
1992	210	110	10	110
2001*	230	320	90	270

* Some of this increase may be attached bars with water next to the original bankline

Table H-3.7 Change from previous data set in reach island area (acres)

Year	Years between data sets	COBL		BLIS		ISRP		RPEB	
		Total change	Change per year	Total change	Change per year	Total change	Change per year	Total change	Change per year
1935	17	-1620	-95	-130	-8	220	13	110	6
1949	14	180	13	-110	-8	-530	-37	-410	-30
1962	13	-180	-14	-80	-7	-250	-19	300	23
1972	10	-220	-22	-120	-12	-60	-7	-80	-8
1984/5	12/13	-70	-6	-10	-1	-30	-2	-140	-11
1992	7/8	60	8	70	8	10	<1	-100	-14
2001	9	20	2	210	23	80	10	160	17

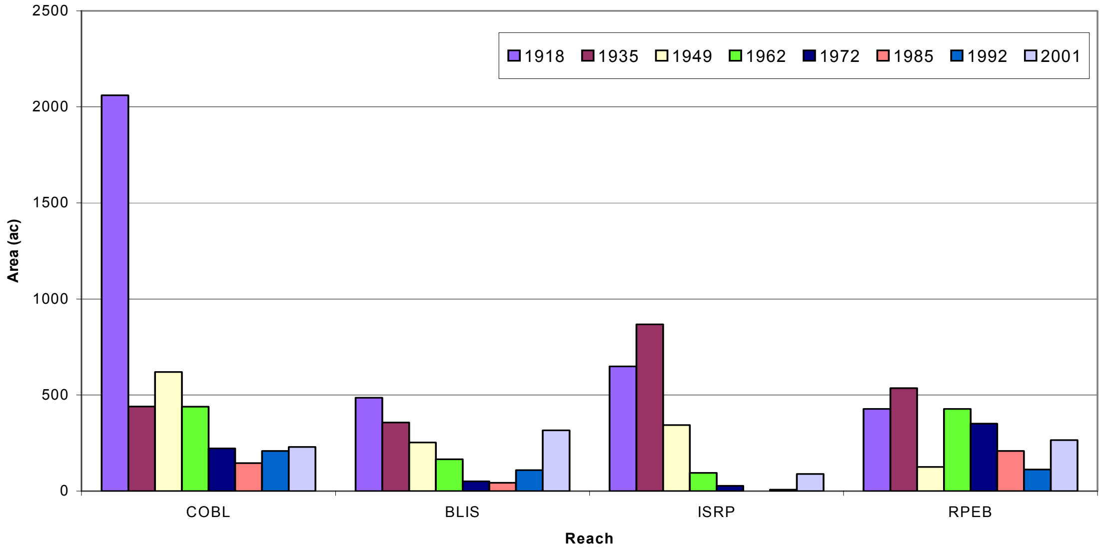


Figure H-3.11 Reach island area over time

In the COBL reach, the 1918 linens showed a multi-channel, anastomosing river with large islands between the channels. Later photos showed less than one-third the area of islands in the same reach. Difficulties in interpreting the maps were the largest in the RPEB reach, particularly in 1918 and 1949. The 1918 data for the most downstream portion of this reach was from a 1908 map as noted previously. The 1908 scale is much smaller and the data for the islands on that map were probably not representative. The 1949 photos showed evidence of recent high flows, with discontinuous water and "fingering" of the channel in the RPEB reach. Again, the data for the islands may not be representative. The reduced discharges and vegetation growth during the dry period after 1992 is the likely cause of much of the island increase shown in 2001 for all reaches. These new island areas may be eroded when higher flows return.

3.5.4 Sinuosity

The Middle Rio Grande is a straight river with a sinuosity of less than 1.2 in all reaches as shown in **Table H-3.8**. Changes between years are very small, (**Table H-3.8**, **Table H-3.9** and **Figure H-3.12**). The COBL and RPEB reaches were less sinuous than the BLIS and ISRP reaches. The sinuosity drops between 1949 and 1962 due in large part to channelization activities of straightening and jack and levee construction. These activities generally continue to limit lateral migration. The recent minor increase in sinuosity is primarily due to channel narrowing and island formation.

Table H-3.8 Reach sinuosity

Year	COBL	BLIS	ISRP	RPEB
1918	1.07	1.13	1.12	1.10
1935	1.06	1.12	1.11	1.09
1949	1.08	1.14	1.13	1.10
1962	1.08	1.12	1.10	1.05
1972	1.05	1.11	1.10	1.05
1984/5	1.07	1.12	1.09	1.03
1992	1.09	1.12	1.10	1.03
2001	1.10	1.14	1.10	1.05

Table H-3.9 Percent change from previous data set in reach sinuosity

		COBL		BLIS		ISRP		RPEB	
Year	Years between data sets	Total change (%)	Change per year (%)	Total change (%)	Change per year (%)	Total change (%)	Change per year (%)	Total change (%)	Change per year (%)
1935	17	-1	<-0.1	-1	<-0.1	-2	-0.1	-1	<-0.1
1949	14	2	0.1	2	0.1	2	0.2	1	<0.1
1962	13	<-1	<-0.1	-1	<-0.1	-2	-0.2	-4	-0.3
1972	10	-3	-0.3	-1	<-0.1	<-1	<-0.1	<1	<0.1
1984/5	12/13	3	0.2	<1	<0.1	<-1	<-0.1	-2	-0.2
1992	7/8	1	0.2	<1	<0.1	<1	<0.1	<1	<0.1
2001	9	1	0.1	2	0.2	<1	<0.1	1	0.2

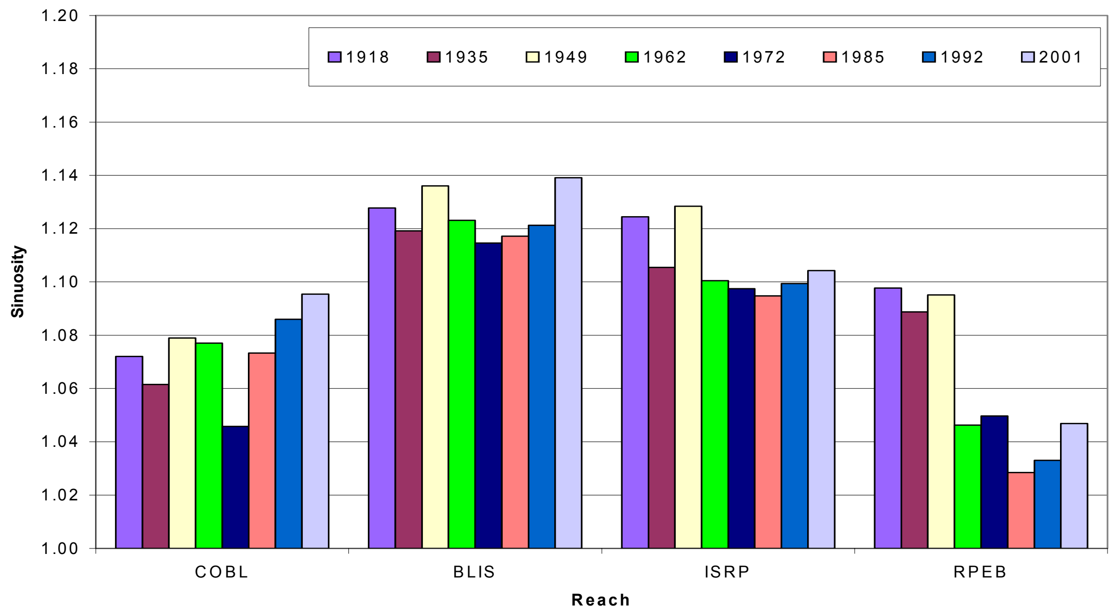


Figure H-3.12 Reach sinuosity over time

3.5.5 Width Analysis

For each year of data, widths by individual cross section (method 2 in section 4.2) were tabulated and statistically analyzed as shown in **Table H-3.10** and **Figure H-3.13**. Analysis includes mean, median, inter-quartile range, maximum, minimum, and standard deviation. The inter-quartile range measures the spread of the central 50 percent of the data (Hensel and Hirsch 1992). General trends for the entire study reach and detailed descriptions for specific areas follow.

Table H-3.10 Channel width statistics for Middle Rio Grande between Cochiti Dam and Elephant Butte Reservoir.

Statistic	1918	1935	1949	1962	1972	1985	1992	2001
Mean	1320	1130	780	470	400	480	440	360
Standard Deviation	750	670	540	330	280	300	240	170
Minimum	150	140	20	20	30	40	60	50
Maximum	5350	5150	3320	2170	1990	1940	1570	940

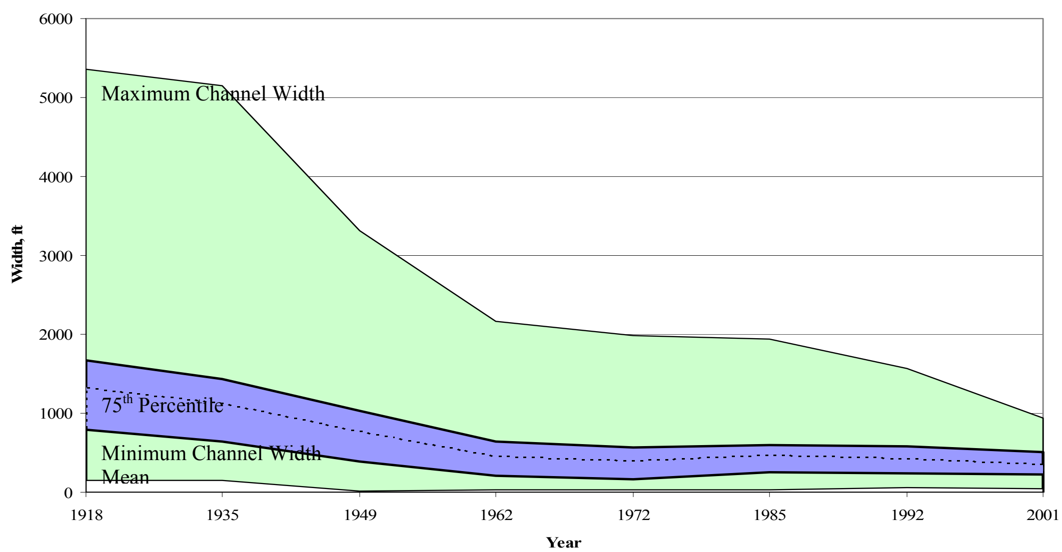


Figure H-3.13 Channel width statistics over time for Middle Rio Grande between Cochiti Dam and Elephant Butte Reservoir.

In general, as discussed previously, widths were widest in 1918 and decrease over time. In 1918 and 1935, the river was very wide. Mean and maximum channel widths (**Table H-3.10**) are greater than 1,000 feet and 5,000 feet respectively. Decreases in width between 1918 and 1935 can be partially attributed to construction of riverside irrigation facilities such as drains and canals that are protected by levees. Widths in 1949 are still very wide compared to present values, but are less than earlier values. Mean and maximum width values decreased to 800 feet and 3,300 feet, respectively. Despite extensive flooding in 1941 (Scurlock 1998), widths had decreased by 1949. Beginning in 1943, drought conditions prevailed and the river channel narrowed by vegetation encroachment on bars and islands that were no longer flooded. By 1962, the mean channel width decreased to less than 500 feet and the maximum channel width decreased to less than 2,200 feet. Drought conditions were still prevalent in 1962, but narrowing was also due to mechanical channelization. Beginning in the 1950s, large sections of the river were narrowed with jetty jacks to more efficiently transport water and sediment downstream. The jacks also trapped sediment and protected the banks. The LFCC between San Acacia Diversion Dam and Elephant Butte Reservoir diverted up to 2000 ft^3/s from the floodway from the late 1950s through the early 1980s. With minor exceptions, the LFCC has not been operated since then, increasing the flows in the floodway. Widths continued to narrow through 1972 as mean channel width decreased to 400 feet. Drought and channelization were largely responsible for the narrowing. Prior to 1985, large sections of the river (floodway) were cleared of vegetation to maintain flood capacity. By 1985, the active channel width widened to near the edge of the cleared floodway. During the period 1979 to 1985, there were high flows in the river. Mean channel width decreased in 1992 and again in 2001. General floodway clearing had stopped before 1992 and vegetation started growing in areas that were not subjected to erosive floodwaters.

Trends for the entire study reach largely hold true for the sub-reaches, see **Figure H-3.14** though **Figure H-3.17**. The rate of decrease was greatest between 1918 and 1962. After 1962, the magnitude of change has been small compared to changes from 1918 and 1962. Similar to the mean width, the interquartile range has also decreased with the largest changes occurring before 1962 and with smaller changes after 1962. Changes in minimum channel width are small, but the greatest rate of change was before 1962. The largest amount of change has been in the maximum channel width. Maximum width values have decreased over 4,000 feet. The greatest rate of change in maximum width was between 1935 and 1949. Between 1962 and 1985, maximum width values decreased slightly. After 1985, maximum width values began decreasing at a faster rate and reached a minimum in 2001. Each period of rapid decrease in maximum width corresponds to periods of bar attachment and island development.

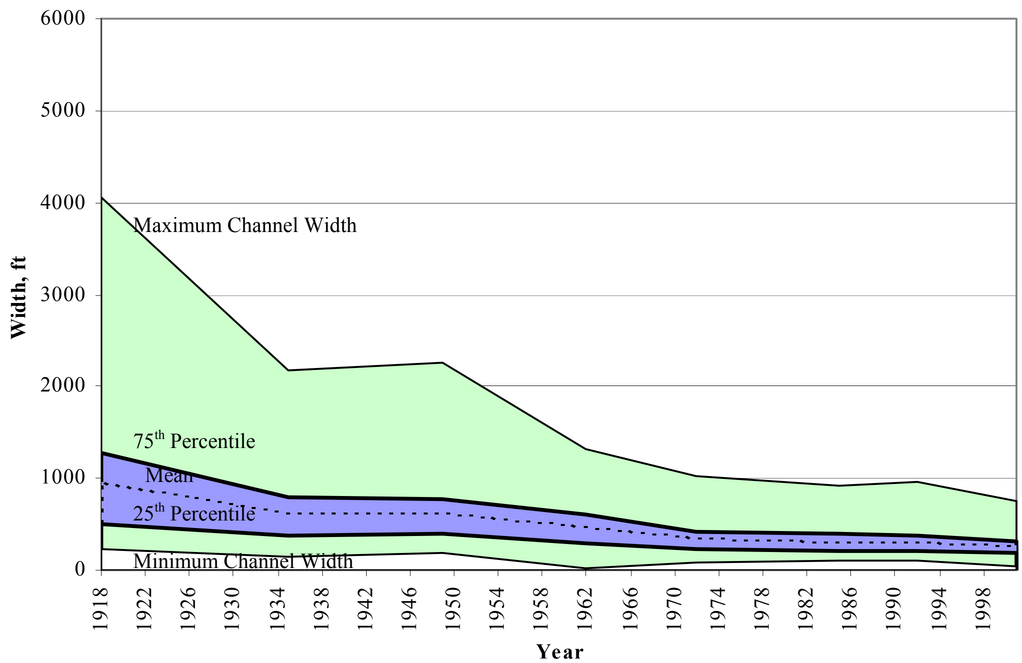


Figure H-3.14 Channel width statistics over time for Middle Rio Grande between Cochiti Dam and Bernalillo.

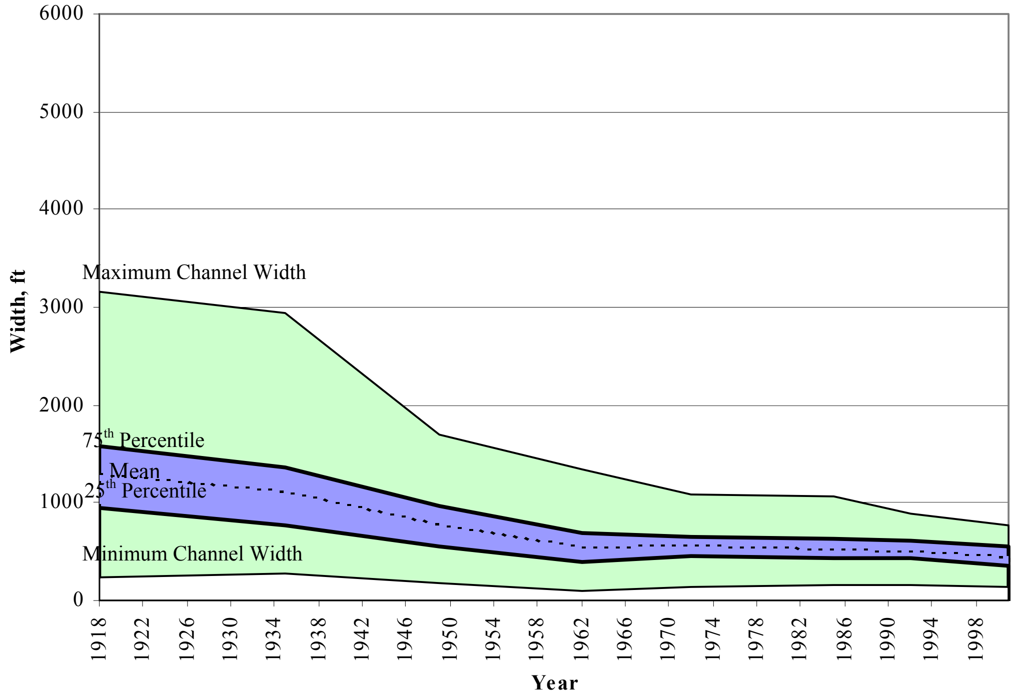


Figure H-3.15 Channel width statistics over time for Middle Rio Grande between Bernalillo and Isleta Diversion Dam.

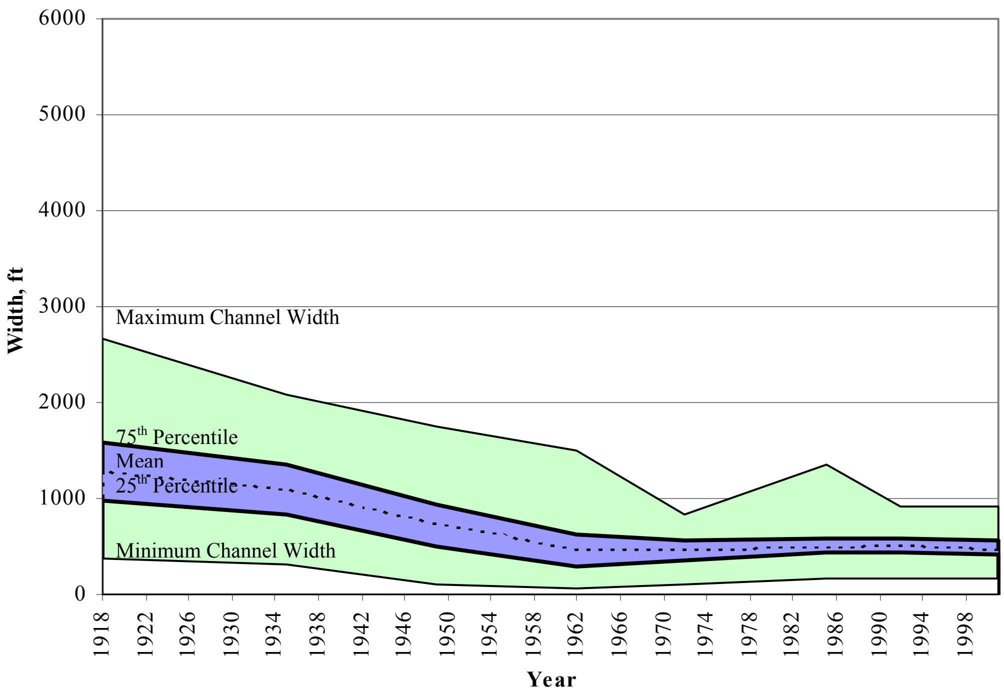


Figure H-3.16 Channel width statistics over time for Middle Rio Grande between Isleta Diversion Dam and Rio Puerco.

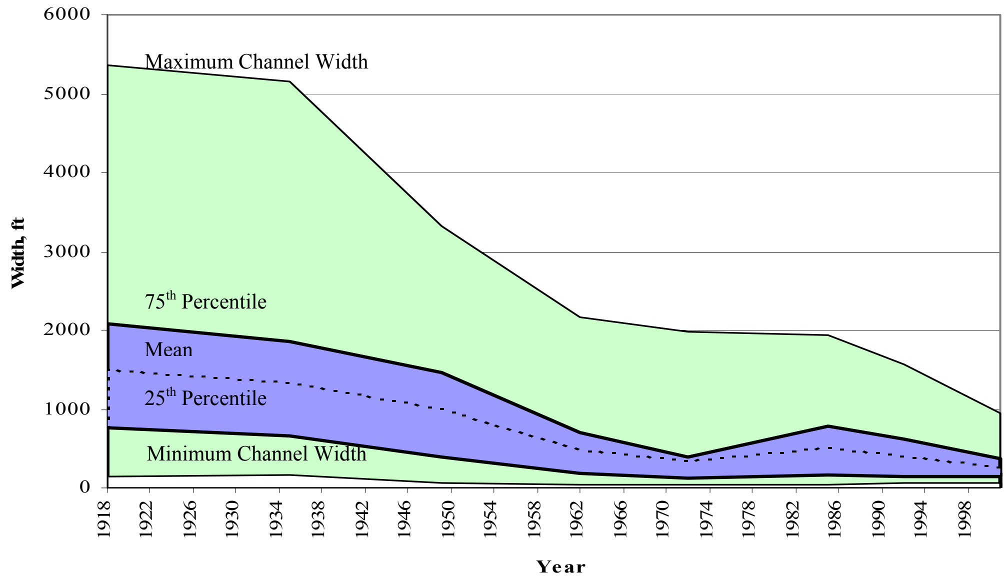


Figure H-3.17 Channel width statistics over time for Middle Rio Grande between Rio Puerco and Elephant Butte Reservoir.

Additional graphs with shorter subreaches can be found in Appendix A. There are a few short subreaches that are exceptions to the general trends. In the area between Angostura Diversion Dam and Bernalillo (river mile 210 – 204), the width increased between 1935 and 1949 (**Figure H-3.18**). The increase in width may be related to the 1941 flood. Historical accounts (Scurlock 1998) indicate that the Jemez River experienced severe flooding, which may have deposited large amounts of sediment in the channel downstream from the mouth of the Jemez River. This influx of sediment may have caused the Rio Grande to temporarily aggrade and widen. The widening would also have a limited range due to geologic constrictions near river mile 210 at the upstream end and near river mile 206 at downstream end of the area.

Another area that does not fit the general trend is between the mouth of the Rio Puerco and San Acacia Diversion Dam. In this reach, the maximum channel width decreased each year data was collected, however the mean width increased between 1918 and 1935 (**Figure H-3.19**). Examination of aerial photographs from 1935 suggests that the increase in mean channel width between 1918 and 1935 and the decrease in 1949 may be due to a combination of events including flooding on the Rio Puerco and construction of San Acacia Diversion Dam (river mile 126.5 – 116). In the 1935 photos, there is evidence of terraces near the mouth of the Rio Puerco that still exist. This suggests that aggradation near the mouth of Rio Puerco, and therefore sediment inputs to the Rio Grande, had occurred prior to 1935. The width increase between 1918 and 1935 may be in response to the high sediment loads coming from the Rio Puerco, especially during the 1929 flood where flows were over 30,000 ft^3/s (Scurlock 1998). In addition, photographs show the area immediately upstream from San Acacia Diversion Dam as being very similar to a delta entering a reservoir. The diversion dam was constructed in 1934 at a natural geologic constriction and sediment was trapped upstream from the dam creating a wide flat surface similar to that of a delta (**Figure H-3.20**). The decrease in width between 1935 and 1949 is likely the result of channel incision though deposited material. As sediment supplies decreased, it is likely that the channel began to incise and narrow. As the channel narrowed, velocity would have increased leading to further incision and narrowing very similar to a feed back loop. The drought conditions beginning in the 1940s tempered the trend with less water to transport sediment.

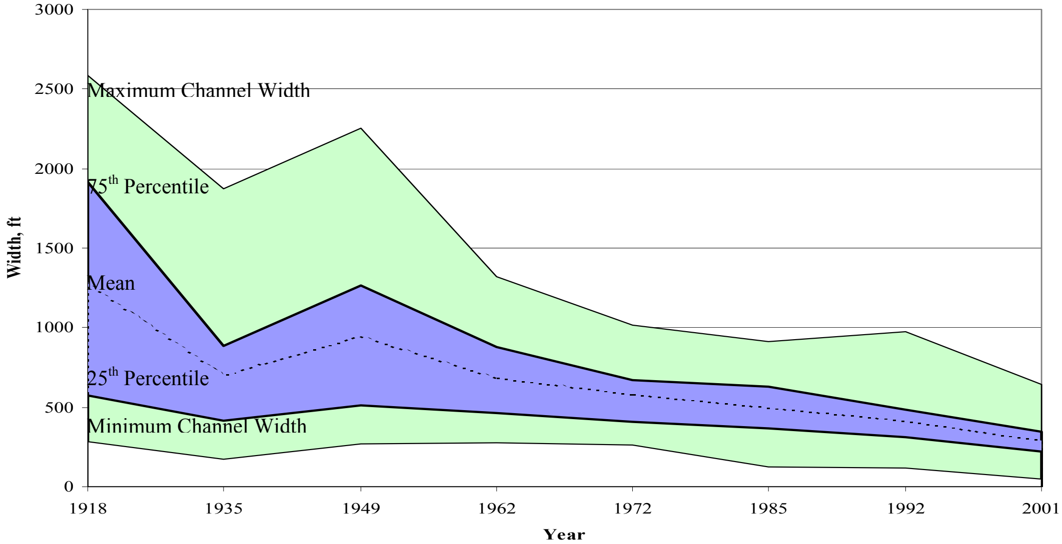


Figure H-3.18 Channel width statistics over time for Middle Rio Grande between Angostura Diversion Dam and Bernalillo.

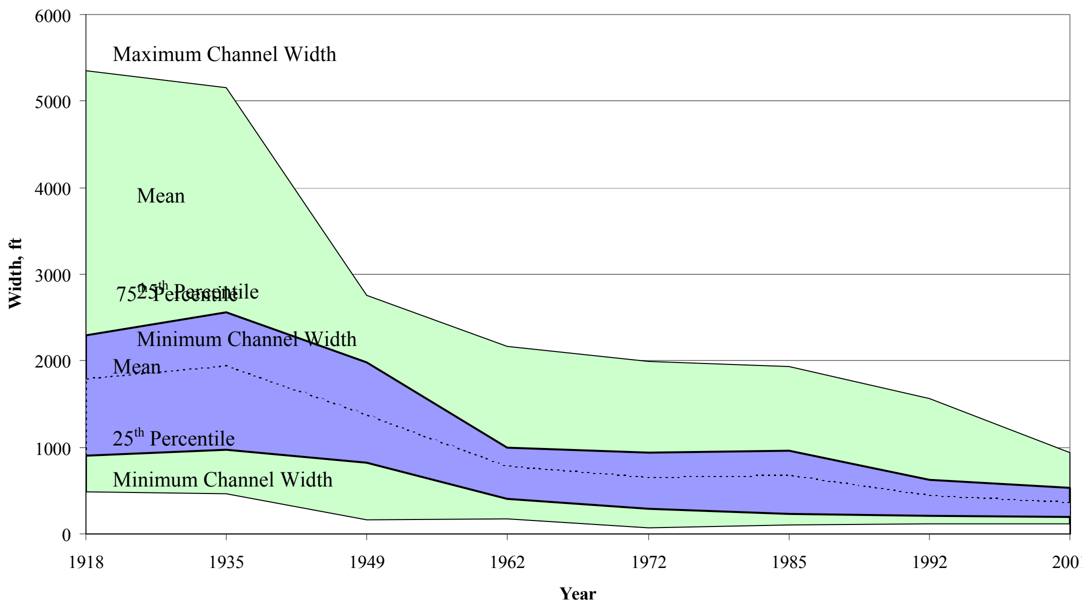


Figure H-3.19 Channel width statistics for Middle Rio Grande between the Rio Puerco and San Acacia Diversion Dam.

Another area that has some unusual trends is between Arroyo de las Canas and the Highway 380 Bridge (river mile 95 – 87). As seen in **Figure H-3.21**, this sub-reach had a large decrease in maximum channel width between 1918 and 1935. The maximum width decreased by over half (2,300 feet) while mean channel width decreased slightly (400 feet). Examination of GIS data and photographs suggest that most of the shift between 1918 and 1935 is due to a new channel location that is upstream from the Highway

380 Bridge. When main channel limits are compared, the 1935 and 1918 channels are similar except for the abrupt change near the bridge (**Figure H-3.20**). In 1918, the channel follows a large meander upstream and east of the bridge. By 1935, the meander bend has been abandoned and the channel follows a much straighter path.

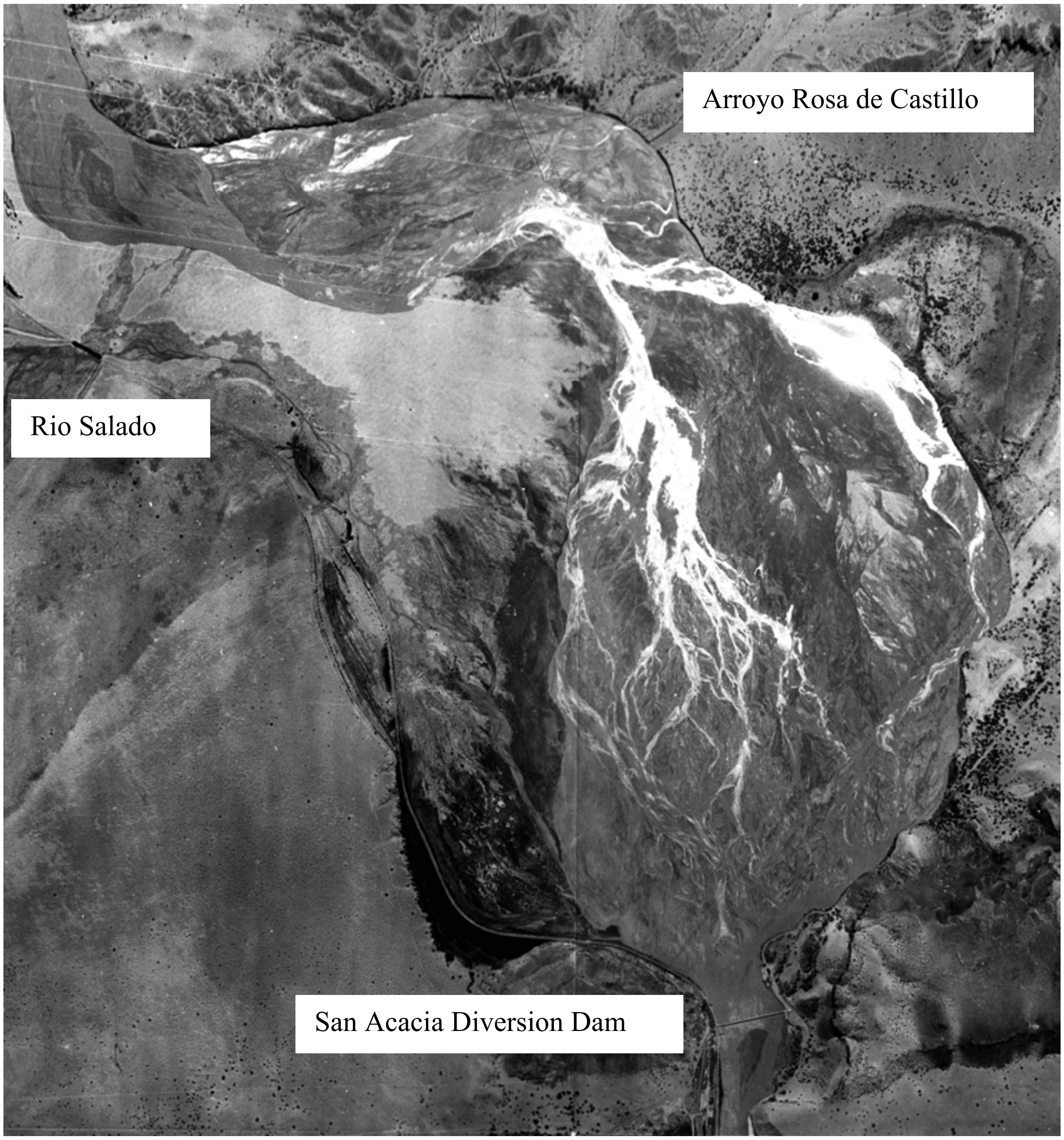


Figure H-3.20 Sediment deposition upstream from San Acacia Diversion Dam in 1935.

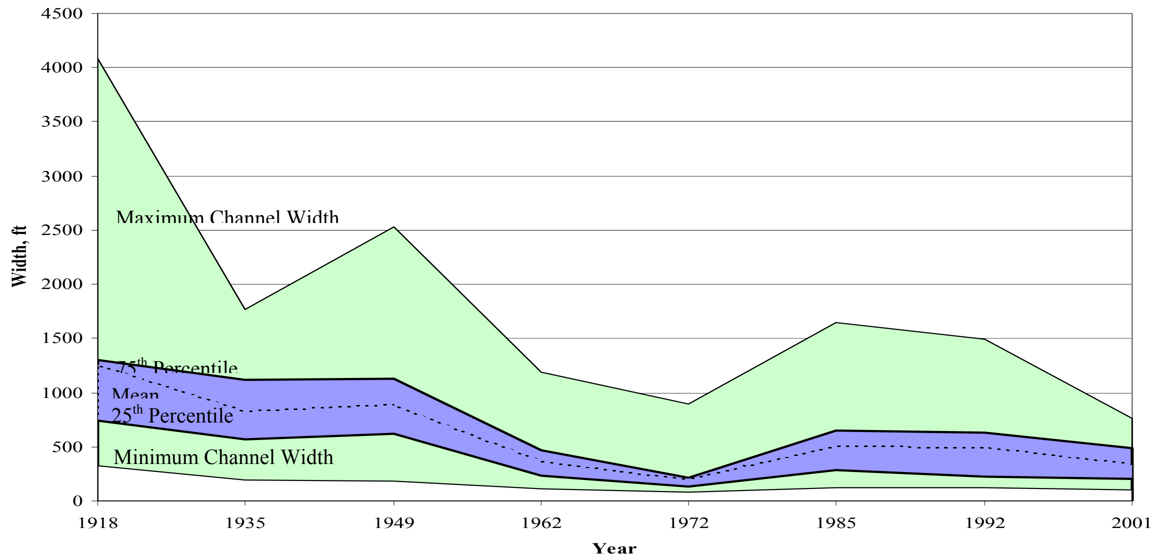


Figure H-3.21 Channel width statistics for Middle Rio Grande between Arroyo de las Canas and Hwy 380.

Figure H-3.23 shows the cumulative width of cross sections for the study reach. Some of the same trends discussed above can be seen in this single mass curve plot. Cross-section widths in 1918 were much wider than widths for other years. In addition, all data show a slope break near agg/deg 1600 (river mile 78). The flatter slope indicates that this part of the study reach has always been narrow during the study period. A general decrease in width between 1918 and 1949 can also be seen in this plot. There is very little difference between widths in 1935 and 1949 upstream of the Albuquerque area (agg/deg 19 – 450). Downstream of agg/deg 470, the curve flattens because the channel widths in 1949 are narrower. The cumulative width curve downstream of agg/deg 1600 is also flatter in 1949 than 1935 indicating narrowing in this period. Between 1949 and 1962, the cumulative width continued to decrease. The mass curve for 1962 has a flatter slope, particularly between range lines 300 and 1200. Much of this area, roughly between Bernalillo and San Acacia, was channelized with jetty jacks in the 1950s. The relatively constant slope of this section indicates that the channel widths were fairly uniform. Downstream of San Acacia Diversion Dam, the slope increases indicating an increase in channel width. The increase in channel width continues into the Bosque del Apache National Wildlife Refuge (agg/deg 1512 – 1637), to approximately river mile 78 where the river was diverted into a constructed channel on the east side of the valley in the 1950s.

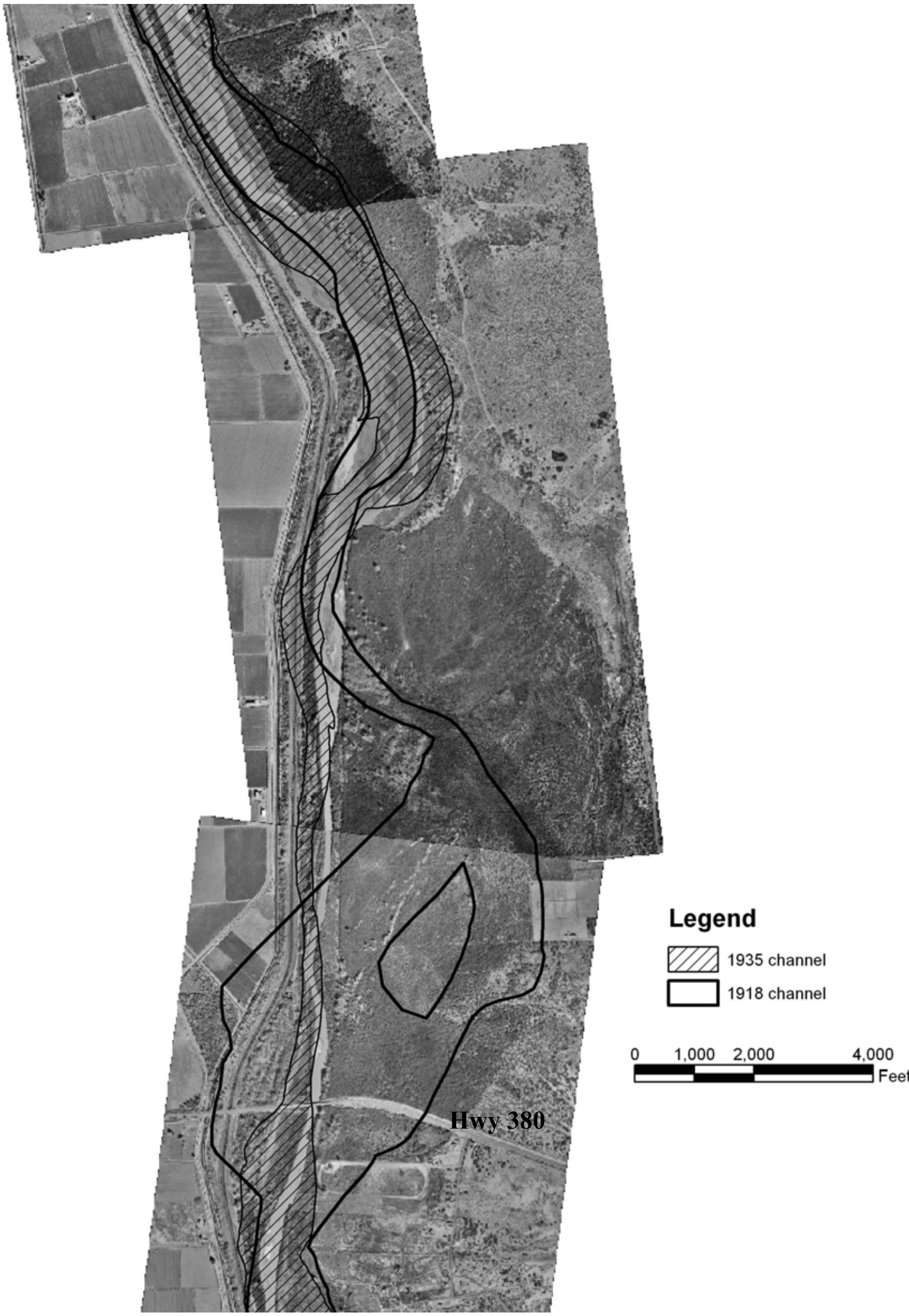


Figure H-3.22 Aerial view of the 1918 and 1935 channels near the Highway 380 Bridge.

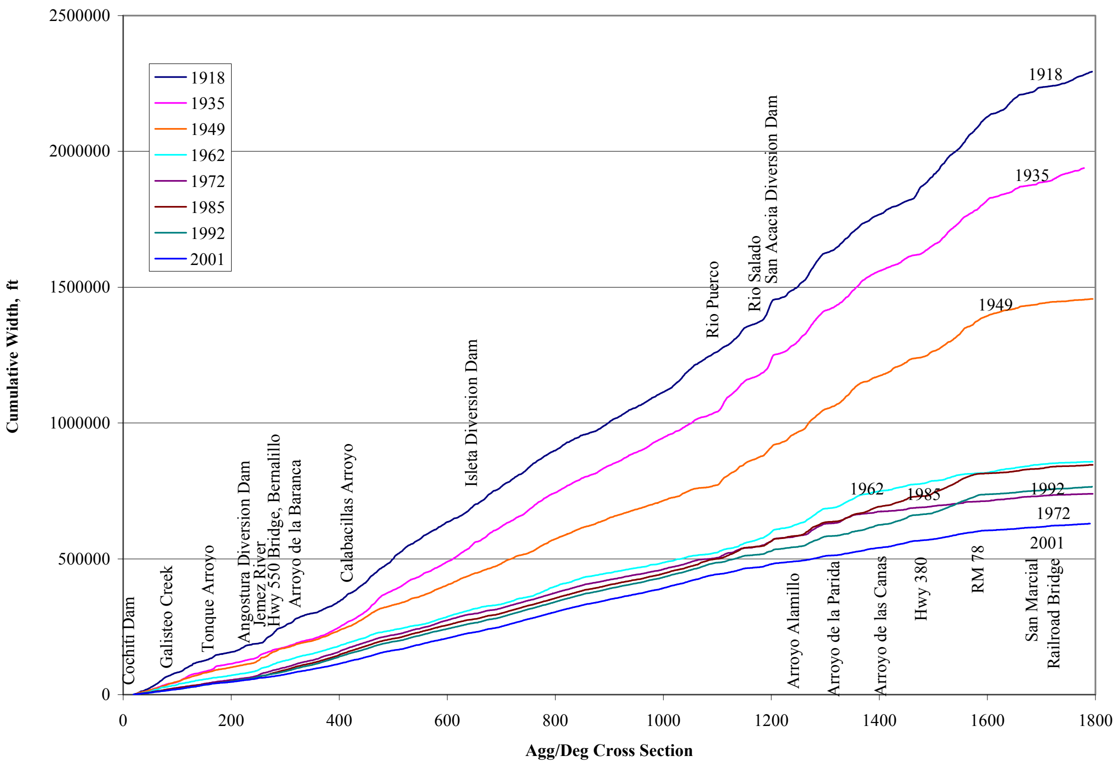


Figure H-3.23 Cumulative channel cross section widths between Cochiti Dam and Elephant Butte Reservoir.

After 1962, cumulative channel widths decrease slightly. In 1972, the section between Bernalillo and San Acacia seems relatively uniform. Downstream from Arroyo de las Canas, channel widths in 1972 are much narrower and uniform as the mass curve follows a very flat slope. Aerial photography shows that much of this section of river was channelized in 1972. Channelization included clearing the floodway and excavating a narrow channel. The mass curve for 1985 indicates channel widening between Arroyo de las Canas and river mile 78. The slope angle continues past the 1972 break as if the river had not been channelized. Cumulative widths for 1992 are smaller than in 1985, but follow the same pattern as 1985. The decrease in cumulative width may indicate a general decrease in channel width rather than an abrupt change. Cumulative widths continue to change, 2001 widths are less than 1992 widths. Between Calabacillas Arroyo and San Acacia the difference in cumulative width is relatively constant; both years appear to have the same slope. Downstream from San Acacia, the difference is more pronounced and the slope of the 2001 mass curve decreases until it reaches river mile 78. At this point, the slope is similar to that of the previous data. The reduced slope of the mass curve between San Acacia and river mile 78 indicates channel narrowing in this reach.

The reach between Cochiti Dam and the Jemez River is particularly interesting. The cumulative width curves remained nearly constant from 1972 to 2001. If Cochiti Dam had a large impact on width adjustment, there should be a noticeable difference between the 1972 and later data, which is not evident. It appears that major width adjustment in this reach had occurred by 1962.

3.6 Conclusions

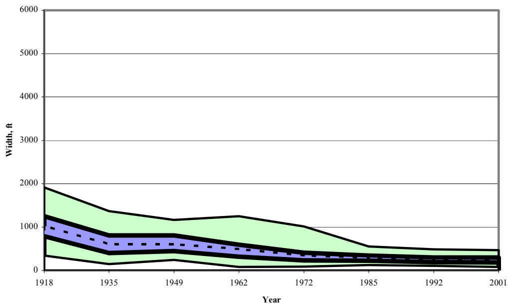
Narrowing of the Rio Grande has resulted from natural processes such as the response to large floods and drought but also has been influenced by anthropogenic modifications including dam construction, river diversions, channelization, and vegetation removal. On rivers like the Rio Grande, channel characteristics are often determined by major flood events (Knighton, 1998). These large events are followed by many years of adjustment, which may include narrowing, incision, and the formation of vegetated islands and bars.

Vegetation plays an important role in width adjustment on the Rio Grande. Once established, vegetation anchors deposited sediments and makes lateral adjustment difficult unless certain thresholds such as shear stress levels or root strength are exceeded. One such example of this is documented by Lagasse (1980). After Cochiti Dam was constructed, there were several years without a bankfull discharge. The relatively low flows allowed vegetation to establish and contain the river into a low flow pattern. When flows finally came up, the river remained in the low flow pattern until a threshold was exceeded and the river returned to a straighter, high-flow pattern. Portions of the Socorro area show channel widening between 1972 and 1985. During the drought years, much of the floodway was cleared of vegetation. When higher flows returned, the channel was able to mobilized the bank sediments and widen up to the vegetation line. After the floodway clearing was stopped, the channel began to narrow as vegetation began to grow on islands and bars that were not scoured clear.

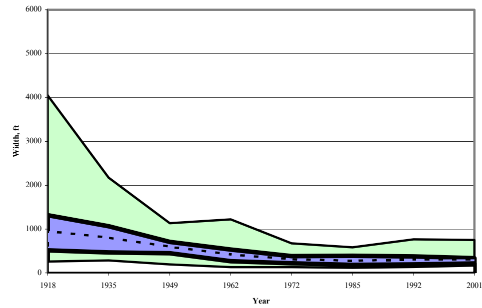
Photography from 2001 and 2002 shows that the development of well established islands has increased in recent years. With uninterrupted and continued development of islands, the wetted channel width will continue to decrease. Eventually, the islands may become attached to the river bankline or alternatively create an incised, anastomosed channel condition. The resulting river is likely to have narrow, high velocity, degraded channel(s) with a slightly increased meandering planform. If the channel incises to a significant degree and floods remain around 5,000 ft^3/s, the floodplain in many sections may become abandoned.

In summary, two main factors contributed to the river morphology changes shown by the data in this report. The first was changes in hydrology. The dry periods during the 1940s through the 1970s and after 1995 decreased the amount of water available in the basin. The second factor overlaps natural hydrology with anthropogenic activities. Flood control dams changed the timing and magnitude of upstream peaks. Dams and diversions changed sediment and discharge relationships. Canals and drains limited the flood plain area with levees. Channelization and bank stabilization narrowed the active channel. Both people and climate have caused planform characteristics of the Rio Grande to change over the years.

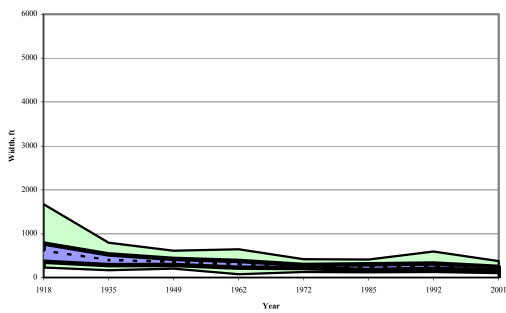
Subreach 1 - Cochiti to Galisteo Cr.



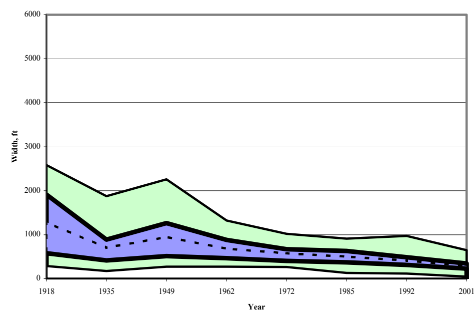
Subreach 2 - Galisteo Cr. to Tonque Ar.



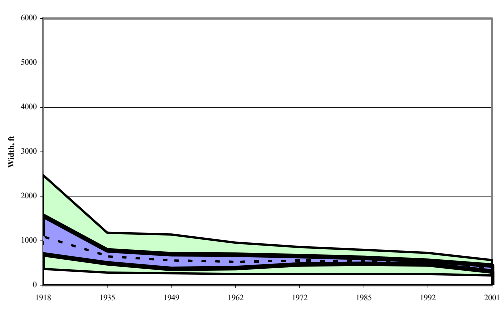
Subreach 3 - Tonque Ar. to Angostura



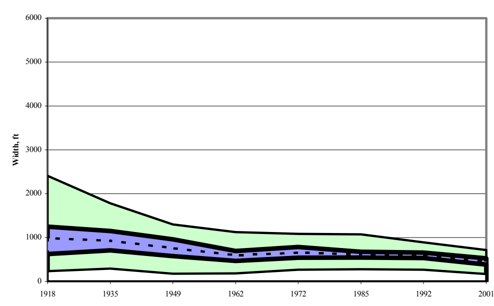
Subreach 4 - Angostura to Bernalillo



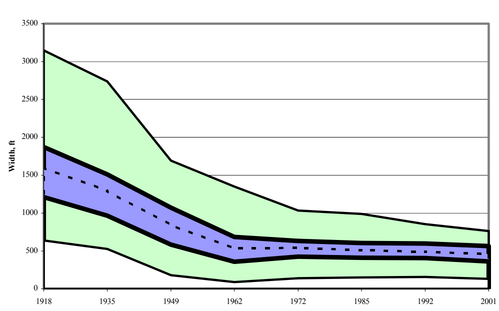
Subreach 5 - Bernalillo to Ar. de la Baranca



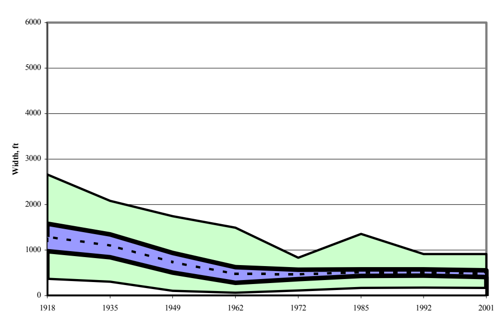
Subreach 6 - Ar. de la Baranca to Calabacillas Ar.



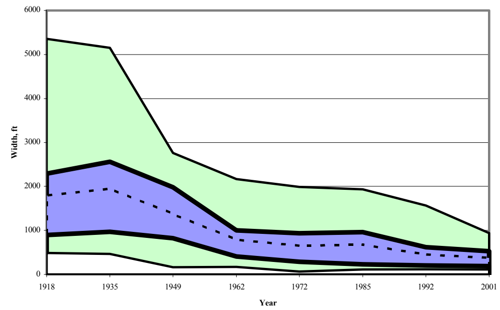
Subreach 7 - Calabacillas Ar. to Isleta DD



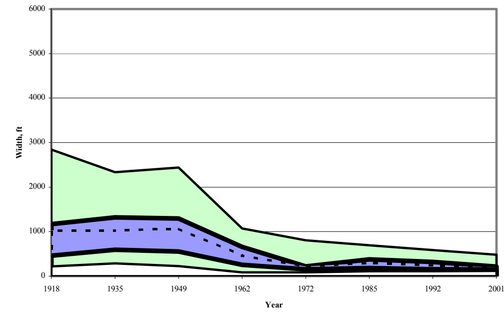
Subreach 8 - Isleta DD to Rio Puerco



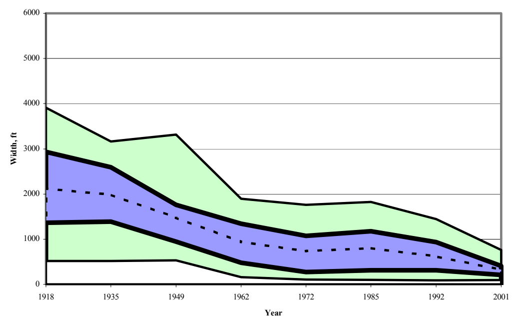
Subreach 9 - Rio Puerco to San Acacia DD



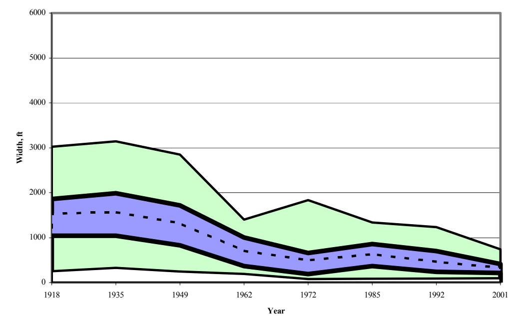
Subreach 10 - San Acacia DD to Ar. Alamillo



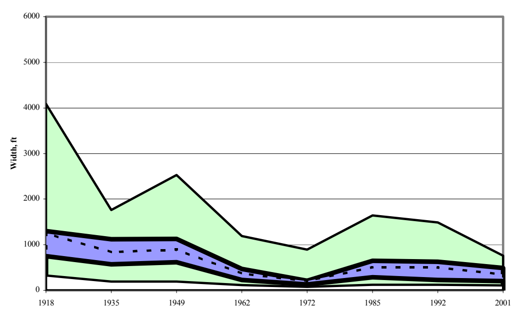
Subreach 11 - Ar. Alamillo to Ar. de la Parida



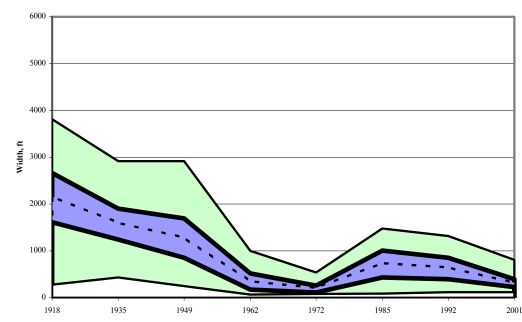
Subreach 12 - Ar. de la Parida to Ar. de las Canas



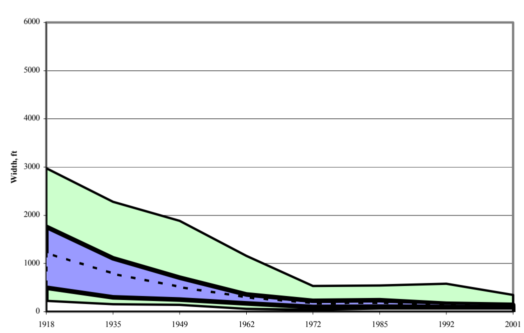
Subreach 13 - Ar. de las Canas to Hwy 380



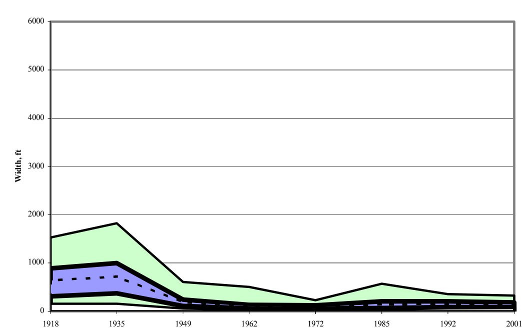
Subreach 14 - Hwy. 380 to RM 78



Subreach 15 - RM78 to San Marcial RR



Subreach 16 - San Marcial RR to Sta. 1800



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4.0 SUMMARY OF URGWOPS BANK ENERGY INDEX ANALYSIS

4.1 INTRODUCTION

An analysis of the relative effects of changes in flow regime on lateral erosion potential along the Middle Rio Grande and Rio Chama was conducted using the Bank Energy Index (BEI) concept. The BEI analysis quantifies energy expenditure against a bank. Although other factors, including bank material characteristics, vegetation and man-made bank protection, affect the actual erosion potential, comparison of BEI values among alternatives provides a basis for evaluating changes in erosion potential at a given site, or among sites that have similar physical characteristics, under different hydrologic regimes. The results from the site-specific BEI analyses were generalized to provide a basis for a qualitative description of changes in lateral migration potential throughout each of the geomorphic subreaches. The analysis included Geomorphic Subreaches 10, 12, 13 and 14 on the Rio Grande between Cochiti Dam and Elephant Butte Reservoir, and Subreach 7 on the Rio Chama between Abiquiu Reservoir and the confluence with the Rio Grande.

4.2 SITE SELECTION

To identify bends that were suitable for the BEI analysis, an initial screening of the bends in the study reach was conducted using recent and historical aerial photography and Geographic Information System (GIS) mapping prepared by the Bureau of Reclamation (BOR) showing bank protection, vegetation coverage and stability, and changes in the historic channel alignment. The initial screening was conducted to identify bends that represented three primary categories:

- Areas that are currently eroding,
- Areas that have significant potential to develop an erosion problem, and,
- Areas that are currently protected by either jack lines or rock revetment.

The initial screening resulted in a list of representative bends for each subreach that exhibit typical characteristics of bends throughout the subreach (**Table H-4.1**). In some cases, the geomorphic subreaches were subdivided to address differences in channel planform, gradient, geomorphology, bed material, and hydraulic tendencies. The bend geometry, defined as the ratio of the radius of curvature to the main channel top width (R_c/W), was considered in the initial site screening to ensure that the range of bend geometries within the subreach were represented. The channel planform, vegetation type and stability, amount of bank protection, and degree of recent or historic lateral migration were also used as criteria in the initial screening. Recent and historical aerial photographs and mapping prepared by the BOR (Oliver 2002) showing existing and historic channel alignments were used to evaluate changes in channel planform and lateral migration rates through time. This information was used to assess the relative stability at each bend. Because a field reconnaissance of the sites was necessary, accessibility issues (including access to Pueblo lands) were also considered in the initial screening.

Table H-4.1 1Summary of subdivided geomorphic subreaches used in the BEI analysis

Table 2.1. Summary of subdivided geomorphic subreaches used in the BEI analysis.				
Geomorphic Subreach	BEI Subreach	Length of Subreach (mi)	Number of BEI Sites	Subreach Limits
7	7	32.0	4	Rio Chama, Abiquiu Reservoir to Rio Grande confluence
10	10a	22.4	5	Cochiti Dam to Jemez River
	10b	4.5	0	Jemez River to Bernalillo
12	12	34.4	5	Bernalillo to Isletta Diversion Dam
13	13	41.7	6	Isletta Diversion Dam to Rio Puerco
14	14a	8.1	2	Rio Puerco to Rio Salado
	14b	2.5	0	Rio Salado to San Acacia
	14c	34.6	5	San Acacia Diversion Dam to RM78
	14d	13.5	5	RM78 to San Marcial

A field reconnaissance to a representative number of the sites from the initial screening was conducted during April 2004. The site visit was designed to assess the local characteristics of the bends that were being considered for analysis to evaluate the extent to which the BEI method would be appropriate, and to qualitatively evaluate the causes of bank erosion where the BEI method was not appropriate. Specific items observed during the site visit included the:

- Cross-sectional geometry of the bend,
- Characteristics of the bank on the outside of the bend,
- Existing channel planform,
- Evidence of recent bank erosion,
- Size and cohesiveness of bank materials,
- Type and stability of bank vegetation,
- Degree of bank protection (jacklines, rock revetment, spur dikes, etc.),
- Other natural controls such as bedrock that would affect the rate of bank erosion,
- Degree to which current aerial photography represents the existing channel planform, and,
- Size of the bed material.

At each site, the flow pattern through the bend was observed to assist in evaluating the causes of bank erosion. Several of the sites that were identified as candidate bends for the BEI analysis in the initial screening were identified as relatively straight high-flow reaches with bends in the low-flow channel. Because the erosion in these areas is caused by shifting of the low-flow channel within the banks and, therefore, are not representative of erosion into the primary river banks, these locations were not included in the BEI analysis. Sites where the channel bend was in contact with an older, high-elevation terrace were noted but eliminated because these areas are typically erosion-resistant.

At numerous sites in the downstream portion of Subreach 14c (below New Mexico Highway 380 bridge) and in Subreach 14d, recent bank erosion into low-elevation bar surfaces was observed. At these locations, the high-flow bankline is currently not eroding since the bar prevents low to moderate flows from impinging on the toe of the bank. To assess the potential loss of riparian habitat located on the bar surfaces, these sites were included in the final selection of bends for the BEI analysis.

The above criteria were used to develop a final selection of 32 sites for the BEI analysis **(Table H-4.2)**. Four sites were selected in Subreach 7 (Rio Chama), five sites were selected in Subreaches 10a, 12, 14c and 14d, and six sites were selected in Subreach 13 and two sites were selected in the relatively short subreach between the Rio Puerco and the Rio Salado (Subreach 14a). No sites were selected in Subreach 14b (Rio Salado to San Acacia Diversion Dam) since the few bends within the subreach are either against the left (east) bank terrace or are in the San Acacia Dam backwater zone. Subreach 10b is entirely within the Santa Ana Pueblo; thus, no sites were selected for this subreach.

Table H-4.2 Summary of selected sites for BEI analysis

Table 2.2. Summary of selected sites for BEI analysis.

Site	RM	Approximate Agg/Deg Line	Easting (m)	Northing (m)	Subreach	Bend Radius (ft)	Main Chnl Top Width (ft)	R_c/W	Energy Grade at Qmch[1]	Vegetation Stability Code[2]	Bank Protection
2	70.3	1681	318184	3728308	14d	1130	135	8.4	0.00038	4s1	None
2a	71	1673	319558	3728792	14d	1100	315	3.5	0.00029	4s1	None
4	73.4	1643	322218	3732216	14d	800	160	5.0	0.00034	4s1, 1s1	None
5	77.4	1591	326598	3738147	14d	730	250	2.9	0.00032	5s1	None
6	77.6	1558	326381	3738406	14d	740	350	2.1	0.00022	5s1, 3s1	None
7	80.8	1551	328440	3743110	14c	410	180	2.3	0.00075	5s2, 5s1	None
8	86.8	1480	328658	3753729	14c	1530	390	3.9	0.00033	5s1, 6a6	Jacklines
12b	110.8	1253	325892	3786251	14c	960	300	3.2	0.00012	2s2	None
14	113.4	1234	325613	3788609	14c	1250	260	4.8	0.00005	5s1	None
14b	114	1226	325118	3789768	14c	750	300	2.5	0.00014	4s1	None
15a	121.4	1153	329924	3796834	14a	2060	250	8.2	0.00058	3s1	None
17a	124.4	1121	328828	3801567	14a	940	660	1.4	0.00024	3s1	None
18	127.6	1088	331232	3806111	13	1350	440	3.1	0.00056	5s1	None
19outside	134.2	1016	334316	3815253	13	1490	680	2.2	0.00093	1s1 (outside) 6a6, 5s2	None
19inside									0.00061		
20	140.6	951	338178	3823317	13	3200	500	6.4	0.00048	3s1	Jacklines
20a	141.6	941	338215	3824903	13	3100	600	5.2	0.00019	5s1	Jacklines
20b	145.3	902	340149	3829540	13	3850	570	6.8	0.00067	5s1	Jacklines
23	162.1	731	343554	3853378	13	3250	570	5.7	0.00059	3s1	Jacklines
26	183.9	504	346143	3884742	12	2580	310	8.3	0.00061	1s1 (outside)	Jacklines
27	184.2	501	345828	3884819	12	1150	340	3.4	0.00061	5s1	Jacklines (set
29	192.7	414	350927	3896722	12	2190	820	2.7	0.00017	Unknown	Jacklines
29a	193	410	351435	3896944	12	1890	860	2.2	0.00089	Unknown	None
30	199	347	354708	3904012	12	1280	300	4.3	0.00052	6a6	None
33a	209.2	241	363159	3916040	10a	910	360	2.5	0.00058	Unknown	None
33b	209.9	234	364535	3916416	10a	1060	430	2.5	0.00049	Unknown	None
34	227.3	70	377136	3936187	10a	540	230	2.3	0.00096	Unknown	Revetment (at
35	227.6	67	376899	3936767	10a	660	270	2.4	0.00123	Unknown	None
35a	227.9	64	377131	3937079	10a	1260	420	3.0	0.00129	Unknown	None
41	Chama	N/A	393538	4003262	7	750	180	4.2	0.00201	Unknown	None
42	Chama	N/A	387715	4008582	7	320	160	2.0	0.00392	Unknown	None
42a	Chama	N/A	376881	4008911	7	480	130	3.7	0.00138	Unknown	None
43	Chama	N/A	375944	4009626	7	420	210	2.0	0.00181	Unknown	None

[1]Qmch refers to discharge that inundates the the main channel.

[2]Vegetation Stability Codes refer to the following:

1s1	Tall trees with well developed understory with canopy covering > 25% of area with significant understory
2s2	Tall trees with well developed understory with canopy covering > 25% of area without significant understory
3s1	Intermediate-sized trees (20-40 ft) with canopy covering > 25% of area with dense undertory
5s1	Shrubby vegetation (0-15ft) covering > 25% of area, with significant understory
5s2	Shrubby vegetation (0-15ft) covering > 25% of area, without significant understory
6a6	Very young shrubby vegetation (0-5ft) covering < 25% of area

4.3 DEVELOPMENT OF BANK ENERGY INDICES

4.3.1 Description of BEI Method

Available analytical methodologies do not allow for detailed predictions of the rate of bank erosion. However, the BEI concept, in conjunction with qualitative information about the bank materials and other site characteristics, provides a means of quantifying the relative effects of changes in the flow regime associated with the EIS alternatives. The BEI is an index of the total energy applied to the banks at specific locations, and is computed based on the hydraulic characteristics of the channel, the channel planform and the magnitude and duration of flows. The BEI, thus, accounts for both the magnitude and duration of stresses imposed on the channel boundary by the flows. It is important to note that the BEI is only an index of erosion potential; other physical factors such as the relative erodibility of the bank materials have a significant effect on the actual erosion that occurs at any specific location.

The BEI is developed from basic physical principles as follows. Energy is defined as the product of the stream power expended on the banks and the incremental time over which it is applied. Bank stream power is the product of the average main-channel velocity (V_{ch}) and the shear stress acting on the bank (τ_b). For a given flood event the total energy expended on the banks at a given location can be determined by integrating the bank stream power over the flood hydrograph:

(1) $$BEI = \int (V_{ch}\tau_b)dt$$

Where

BEI= total energy expended at a specific bank location, and

Dt = the incremental time associated with each range of discharge in the flow record.

The bank shear stress is computed from:

(2) $$\tau_b = K_b \gamma d_h S_f$$

Where

γ = unit weight of water (62.4 lb/ft3),

d_h = hydraulic depth,

S_f = energy slope, and

K_b = factor that accounts for the effect of channel curvature on the shear stress acting on the outside of a bend.

K_b depends on the ratio of the radius of curvature to the channel topwidth (R_c/W), as shown in **Figure H-4.1**.

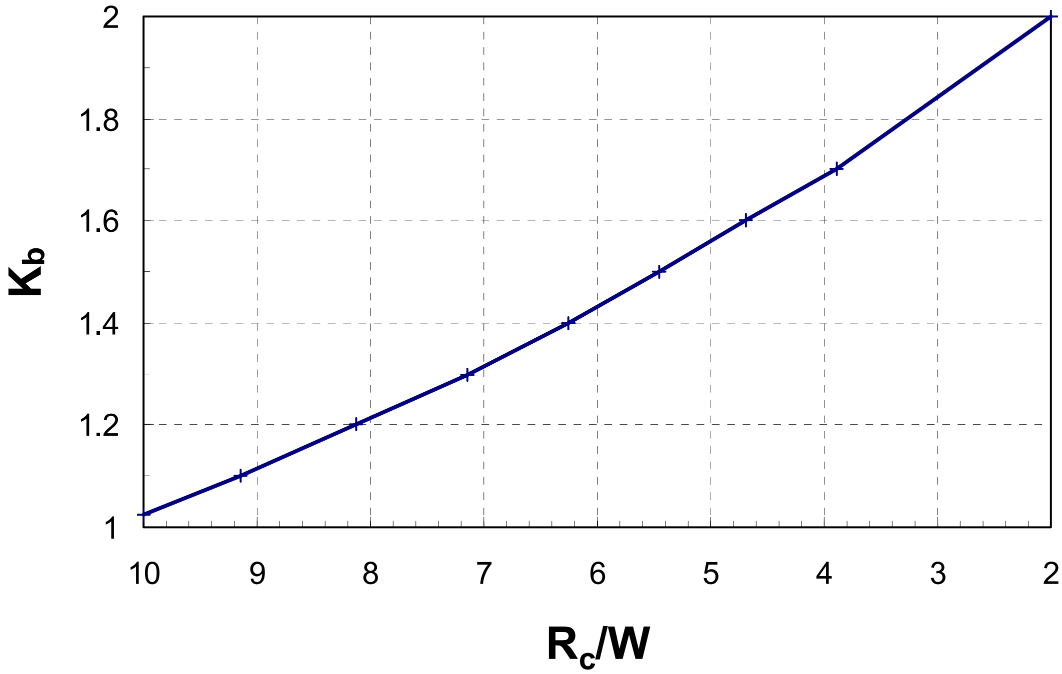

Figure H-4.1 Bend shear factor (K_b) as a function of the bend geometry (R_c/W).

4.3.2 Data Sources and Assumptions

Hydrologic information was obtained from the 40-year flow simulations that were performed by the Water Operations Team using the URGWOM planning model. The information included mean daily flows for the no-action alternative and each of the six action alternatives for various locations in the study reach. Mean daily flow-duration curves at five locations on the Rio Grande in Geomorphic Subreaches 10 through 14 and one location on the Rio Chama in Geomorphic Subreach 7 were developed by S. Waltemeyer (USGS), and were provided to MEI for use in this investigation.

Hydraulic parameters necessary for computing the BEI at each of the selected sites was based on output from the FLO-2D model of the reach developed by Tetra Tech and the Hydraulics Team. An interactive post-processing program that was provided by the Hydraulics Team to retrieve output from the model was used to generate rating curves of the hydraulic parameters at each of the sites. Except for very sharp bends that included only one FLO-2D element, the rating curves were developed by averaging the hydraulic data over the range of elements included in the bend. Rating curves were developed for main channel velocity, hydraulic depth, main channel topwidth, and energy gradient for the range of discharges encompassed by the URGWOM runs.

The bend geometry at each of the selected sites was obtained from 2002 aerial photography and data from recent surveys of the BOR rangelines. The photography covered the entire study reach except those portions on Pueblo lands. The bend radius was computed by fitting a circle to the primary flow path through the bend. The channel top width was also measured between the banks from the aerial photography (generally using the limits of the mature vegetation to define the banks). **Figure H-4.2** provides an example of the measured bend radius of curvature and top width. Cross-section plots developed from the rangeline surveys located near the bend were used to verify the measured top width. Because the FLO-2D model results were based on rangeline survey data, the plotted cross sections were also used to validate the model output by comparing the FLO-2D geometry to the channel planform in the 2002 aerial photographs.

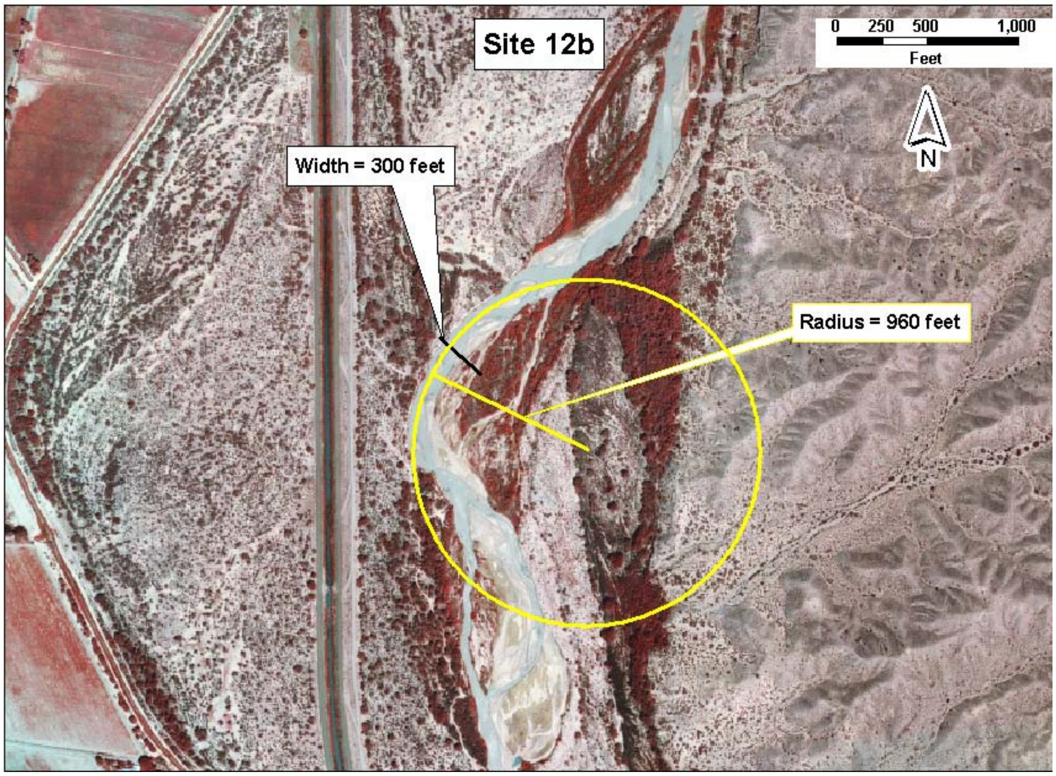

Figure H-4.2 Aerial photograph showing an example of the measured bend radius of curvature and top width (Site 12b).

The bend shear stress was computed for the range of modeled discharges using the computed rating curves for the energy slope and main channel hydraulic depth, along with the appropriate K_b factor. R_c/W values used in the calculations were based on either the modeled topwidth, when less than the measured topwidth, or the measured topwidth.

Appendix A provides the bend geometry and hydraulic information used at each of the bends. For each site, a recent aerial photograph showing the existing radius of curvature, the measured channel topwidth, existing and historic channel alignments, and bank protection through the bend is provided. Rating curves summarizing the computed hydraulics as a function of discharge at each site are also presented, including main channel velocity, main channel stream power, main channel topwidth, and the bend shear factor (K_b).

4.3.3 BEI Analysis Results

A comparison of the computed BEI values within each subreach and over the entire study reach provides an indication of the relative amount of erosive energy that is available to drive the erosion process. In general, the energy available for bank erosion is greatest in areas with locally steep channel slopes and narrow channel widths, which result in high velocities and bend shear stresses. Potential lateral migration is also affected by the bend geometry. In general, bends in comparable materials with R_c/W values in the range of 2 to 4 have the highest erosion potential (Nanson and Hickin, 1983). Milder bends (i.e., $R_c/W>4$) tend to erode at slower rates because the stress on the outside of the bend is less than in sharper bends. For bends with R_c/W less than about 2, significant energy loss occurs in the bend, and bend cutoff, rather than progressive lateral migration, typically occurs. For sites having comparable erodibility, based on material types and vegetation, higher BEI values indicate higher erosion potential. To facilitate comparison among sites and alternatives, the computed BEI values at each site were normalized to the overall reach-averaged BEI value for the No-Action Alternative.

4.3.4 No-Action Alternative Results

Figure H-4.3 shows the normalized BEI values under the No-Action Alternative for the entire study reach (with the subreaches delineated with different bar symbols), and includes the R_c/W values at each of the sites. The figure shows the relative effects of the channel gradient, with relatively high BEI values in the steeper, upstream subreach (Subreach 10) and progressively lower BEI values proceeding downstream, where the channel gradient is flatter (**Figure H-4.4**). **Figure H-4.3** shows a relatively large degree of variability in BEI values throughout the reach. The information presented in Appendix A provides detailed information about each of the sites that will aid in understanding the following discussion.

In Subreach 14d (RM 78 to San Marcial), the BEI values range from about 0.2 up to nearly 1.0. Results at Sites 2 and 4 have the highest R_c/W values, but the channel geometry through the bends causes high channel velocities and steep energy grades, resulting in relatively large bank shear stresses. The relatively thick vegetation at these sites provides significant resistance to bank erosion. Conversely, despite the relatively sharp curvature (low R_c/W) of the bends at Sites 2a, 5 and 6, the wider channel at these locations causes lower velocities and energy gradients, resulting in relatively low bank shear stresses. The bend at Site 2a is currently stable due to the presence of vegetation. A comparison of current and historic aerial photographs of the adjacent bends through Sites 5 and 6 indicate migration of the low-flow channel within the bank margins over the past few decades, but very little erosion into the primary channel banks. Shifting of the low-flow channel into the vegetated bars may affect riparian habitat, but migration of the overall channel is not expected.

In Subreach 14c (San Acacia to RM 78), the largest BEI value occurs at Site 7, and represents the potential for bank erosion into the attached low-elevation bar (**Appendix A**). The jacklines and vegetation at Site 8 have stabilized the bank, and if left in place, will likely continue to limit lateral migration. Sites 12b, 14, and 14b are representative of areas currently experiencing significant bank erosion between Escondida Bridge (RM 104.8) and the San Acacia Diversion Dam (RM 116.2). The computed BEI values at these sites are relatively low due to the locally flat channel gradient and mild bend curvatures (high R_c/W values), but the incised nature of the channel, combined with a lack of stabilizing vegetation, results in a significant lateral migration tendency.

The two bends evaluated in Subreach 14a (Rio Puerco to Rio Salado) have BEI values ranging from 0.6 to 1.1. Both bends in Subreach 14a have moderate vegetation, but are not protected with jacklines. Future erosion at these sites could affect the west levee if bend migration continues.

Except for the downstream two sites in Subreach 13 (Sites 18 and 19), the majority of sites evaluated are protected with jacklines. The bends that are protected with jacklines typically have relatively mild curvature (minimum R_c/W=5.2), with wide cross sections that result in low energy expenditure on the banks. BEI values for the protected bends in this subreach range from 0.3 to 0.9. A moderate BEI value at Site 18 (BEI=1.2), coupled with minimal bank vegetation, indicates potential for bank erosion that may threaten the west levee.

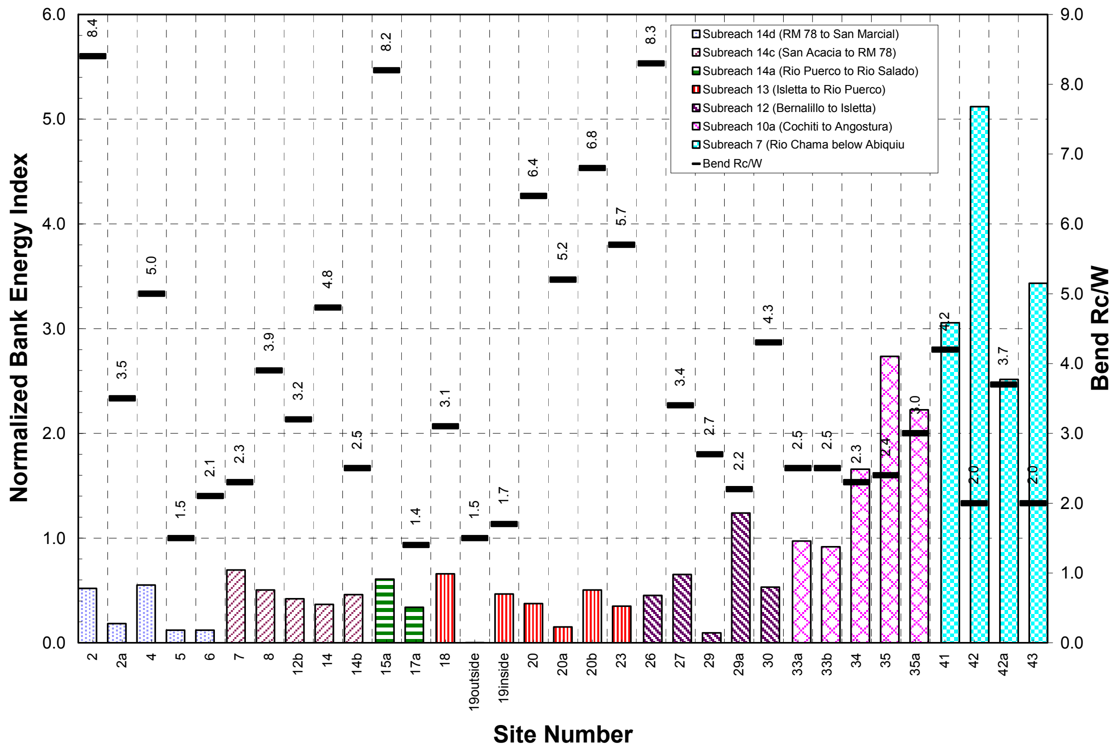

Figure H-4.3 Normalized BEI values for each of the selected sites for the No-Action Alternative.

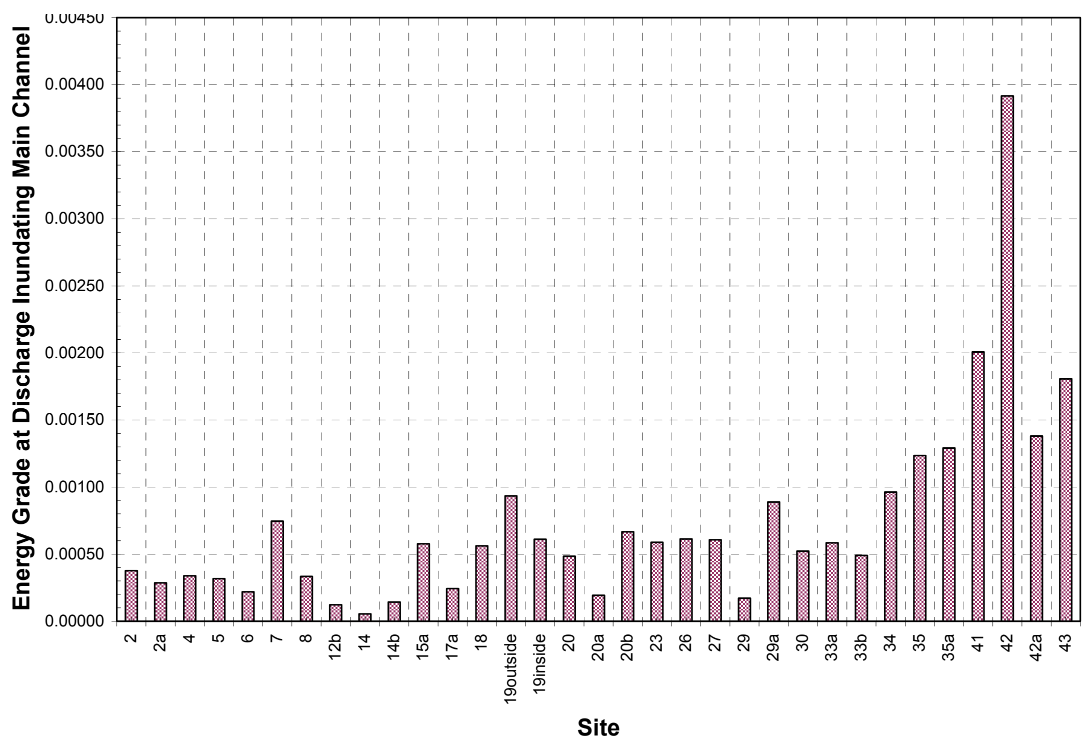

Figure H-4.4 Summary of the FLO-2D computed energy gradients at the discharge that inundates the entire bed of the main channel at each of the selected sites.

The bend at Site 19 has two well-defined surfaces that could be subject to erosion. As shown in **Figure H-4.5**, the outer bank is subject to erosion at discharges capable of overtopping the attached low-elevation floodplain surface (Q>4,500 cfs). The edge of the inside floodplain surface is subject to erosion for the entire range of discharges. The BEI analysis was conducted for the outside bank surface to evaluate potential risk to the west bank levee, and was carried out for the inside floodplain surface to assess the impacts of the EIS alternatives on riparian habitat. **Figure H-4.6** shows the computed bend stream power for the inner floodplain surface and outer primary bank. Because the entire range of flows result in bend shear on the inside surface, the BEI value is similar to other sites in the subreach (BEI = 0.8). However, since only the infrequent flows above 4,500 cfs reach the outer bank, the BEI value for the higher surface is insignificant (BEI = 0.003). If the low elevation surface is eroded away, as it was in the early 1990s, the outer bank would be subject to erosion over the full range of flows and the BEI value would also be similar to other sites within the reach.

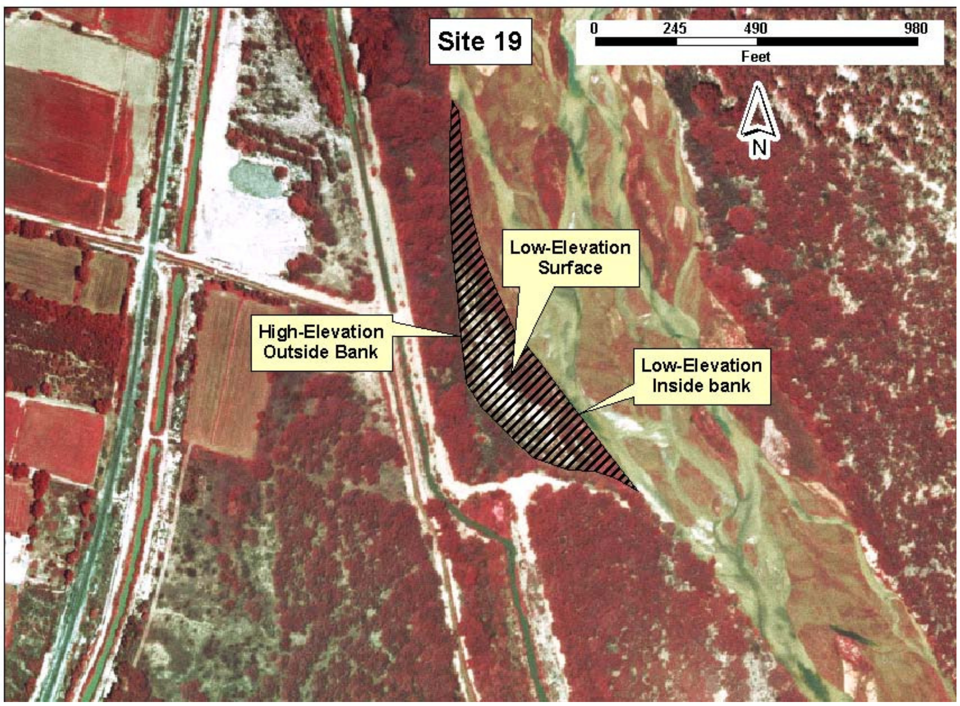

Figure H-4.5 Aerial photograph showing the high outer bank surface and the low-elevation floodplain surface through the bend at Site 19.

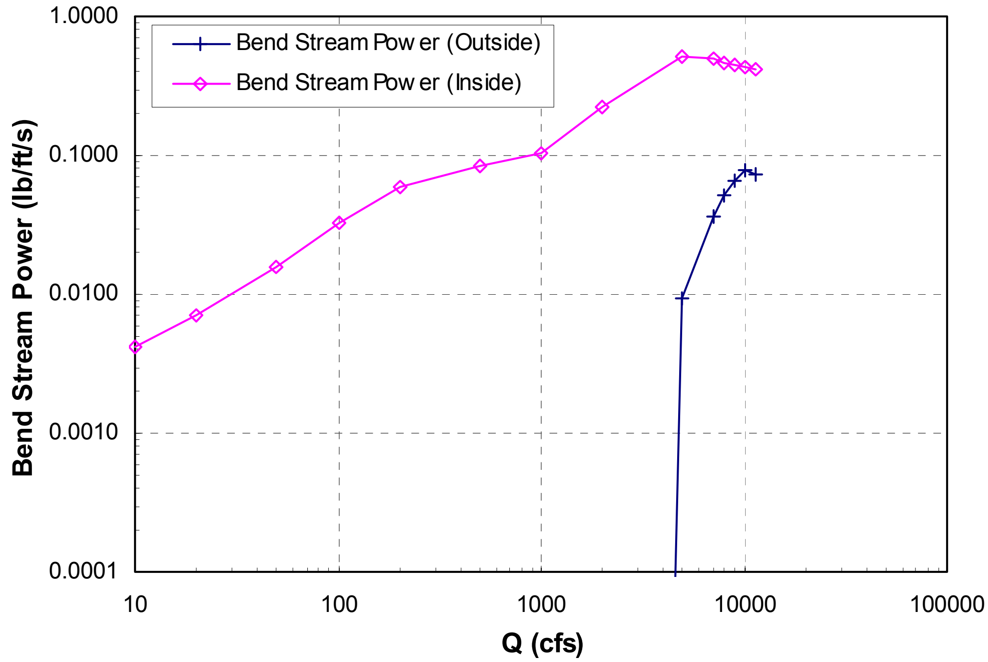

Figure H-4.6 Computed bend stream power rating curves for the low-elevation, inside bank surface and for the high-elevation outside bank surface at Site 19.

The variability in the BEI values computed for sites within Subreach 12 is a result of the range of bend and channel geometries throughout the subreach. Both bends at Sites 26 and 27 are protected with jacklines, but since the jacklines at Site 27 are set back from the active bankline, migration of the bank is possible. Significant bank migration is not expected at Site 26 due to the presence of jacklines along the top and toe of the bank. Although the majority of the bend at Site 29 is protected by jacklines, the upstream portion of the bend (Site 29a) is unprotected. The bend through Site 29a is slightly more sharp ($R_c/W = 2.2$) than the downstream portion through Site 29, but the hydraulics at Site 29a are affected by the large, vegetated mid-channel bar that increase the bend shear stress. A comparison of the BEI results at Sites 29 and 29a may aid in an evaluation of the effects of jack removal. Erosion of the bend at Site 30 is somewhat limited by dense bank vegetation, which may be suitable protection for the west levee.

The variability of the computed BEI values at the selected sites within Subreach 10a are primarily due to differences in hydraulics, since the bend geometries are very similar. The bends evaluated in this subreach are relatively sharp (R_c/W values ranging from 2.3 to 3.0). A comparison of current and historic aerial photographs indicates that Sites 33a and 33b have been stable over recent decades, perhaps due to the presence of stabilizing bank vegetation. The BEI values for the bends at Sites 34, 35, and 35a (located near Pena Blanca) indicate high potential for bend erosion, primarily due to the steep channel gradients in this area. The downstream portion of the bend at Site 34 has been protected with a spur dike, which is likely to inhibit further bank erosion. The bends at Sites 35 and 35a are unprotected, but future bank migration does not appear to endanger any existing infrastructure.

BEI values in the Rio Chama (Subreach 7) are higher than in the Rio Grande downstream from Cochiti Dam due primarily to the steeper channel gradient. At each of these sites, bank erosion was observed during the field visit. The analyzed bends in Subreach 7 represent typical areas of the Rio Chama with minimal vegetation and fine-grained, noncohesive bank material that are susceptible to erosion. Although shifting of the channel is expected throughout the subreach, no existing infrastructure is endangered at the selected sites.

4.3.5 Results for the EIS Action Alternatives

To evaluate the effects of altered flow regimes associated with the six EIS Action Alternatives on bank erosion potential, the normalized BEI values were computed for the selected sites under each alternative flow scenario (**Figures H-4.7 through H-4.11**). (As discussed above, the computed BEI values at each site were normalized to the overall reach-averaged BEI value for the No-Action Alternative to facilitate the comparisons.) The first figure in each set shows the normalized BEI value at each of the sites that were analyzed, and the second figure shows the percent change from the No-Action Alternative.

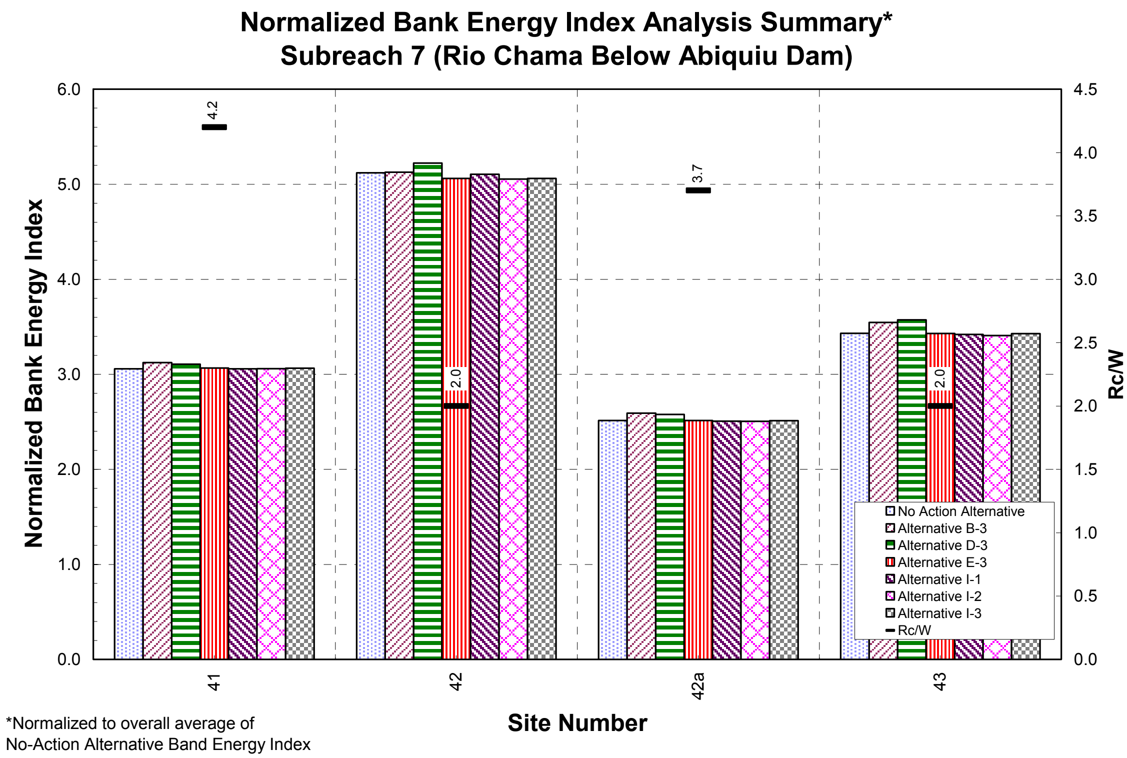

Figure H-4.7a Normalized BEI values for the selected sites in Subreach 7a.

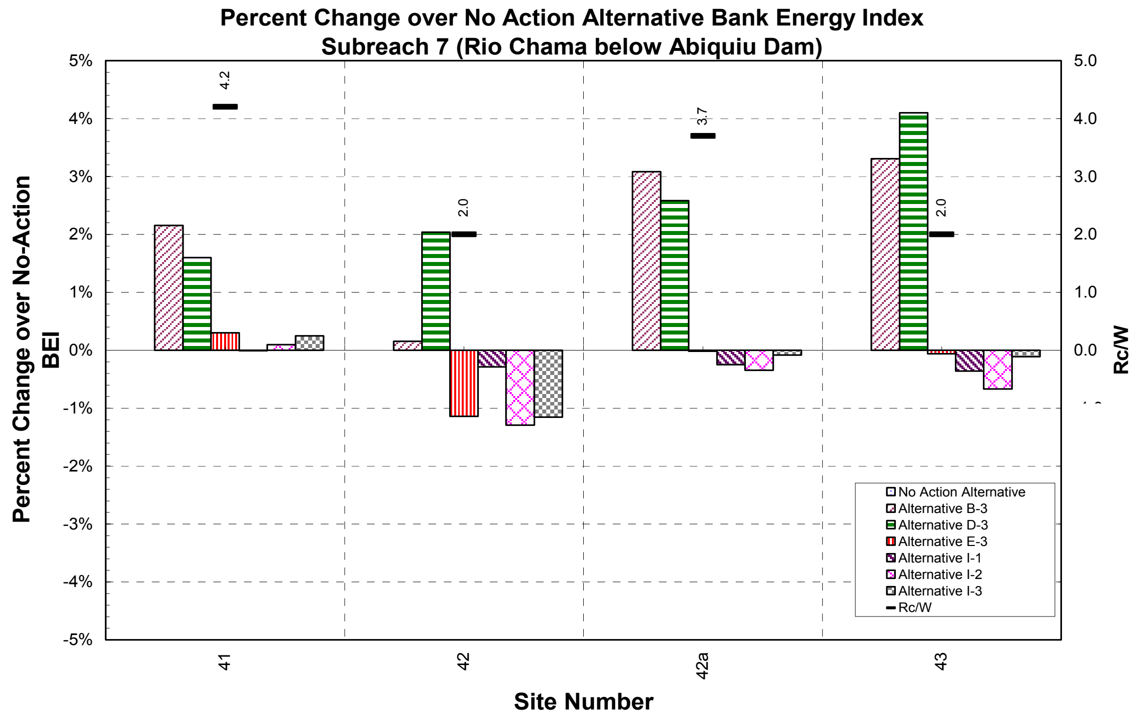

Figure H-4.7b Percent change in BEI values over the No-Action Alternative for selected sites in Subreach 7a.

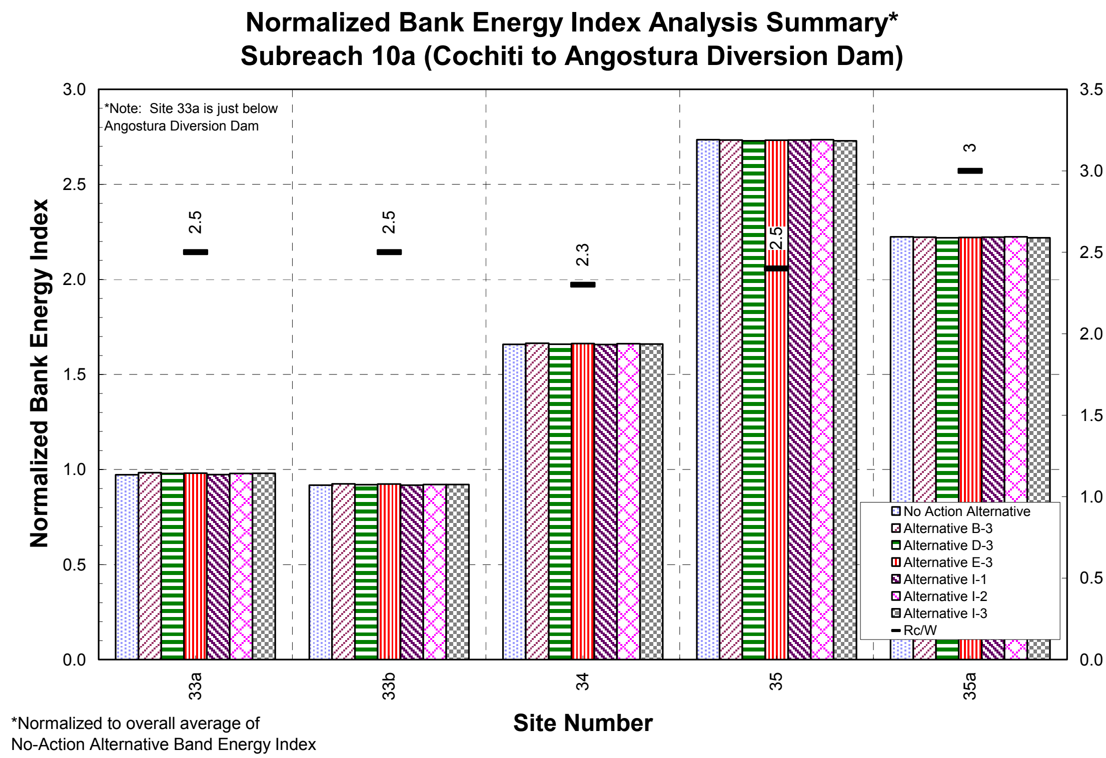

Figure H-4.8a Normalized BEI values for the selected sites in Subreach 10a.

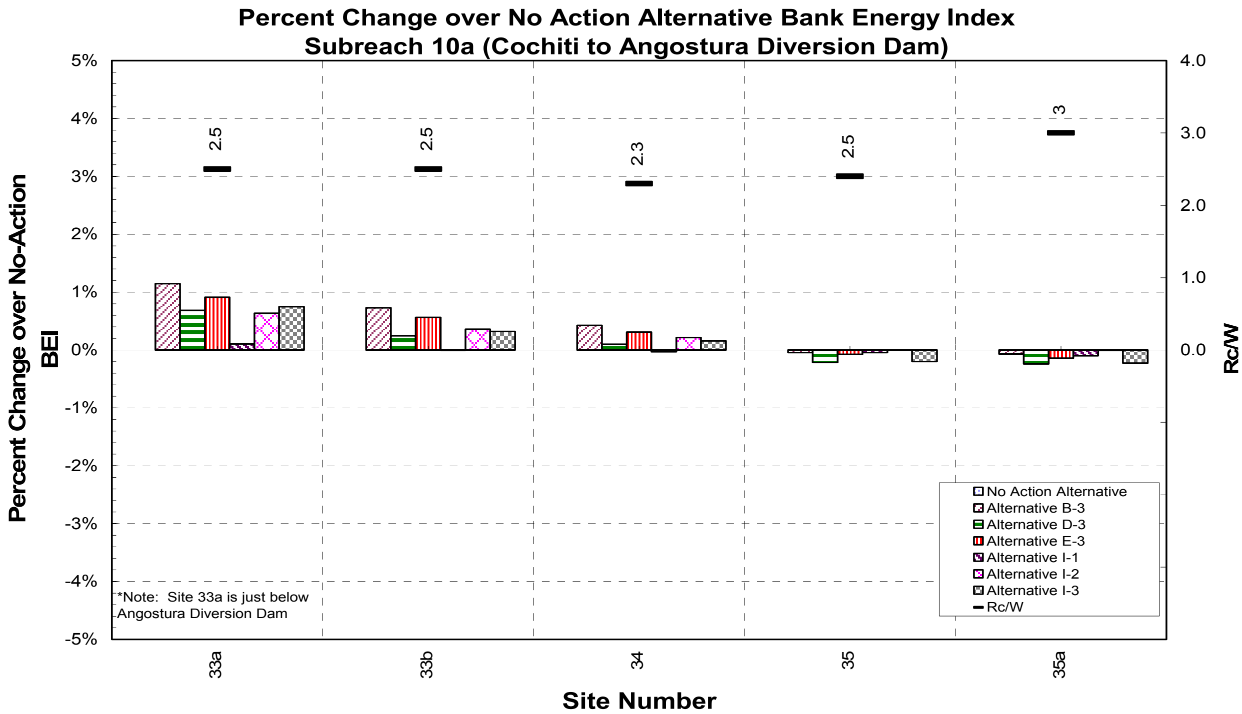

Figure H-4.8b Percent change in BEI values over the No-Action Alternative for selected sites in Subreach 10a.

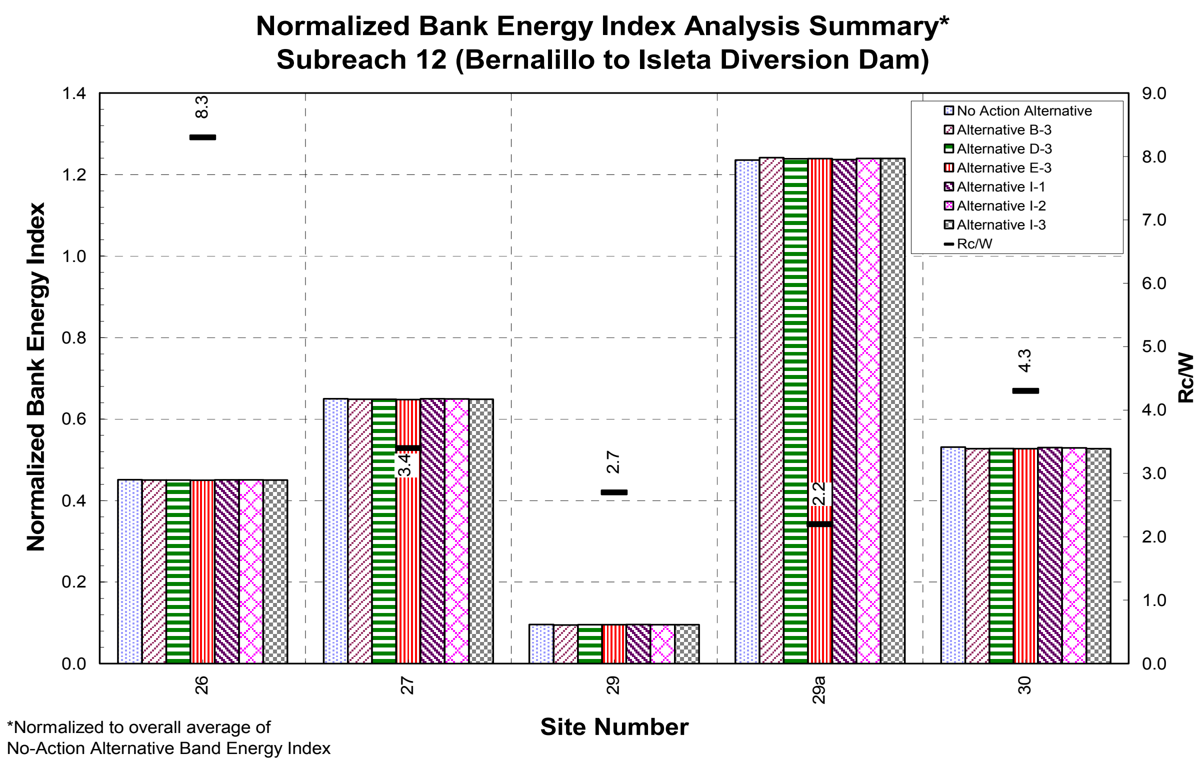

Figure H-4.9a Normalized BEI values for the selected sites in Subreach 12.

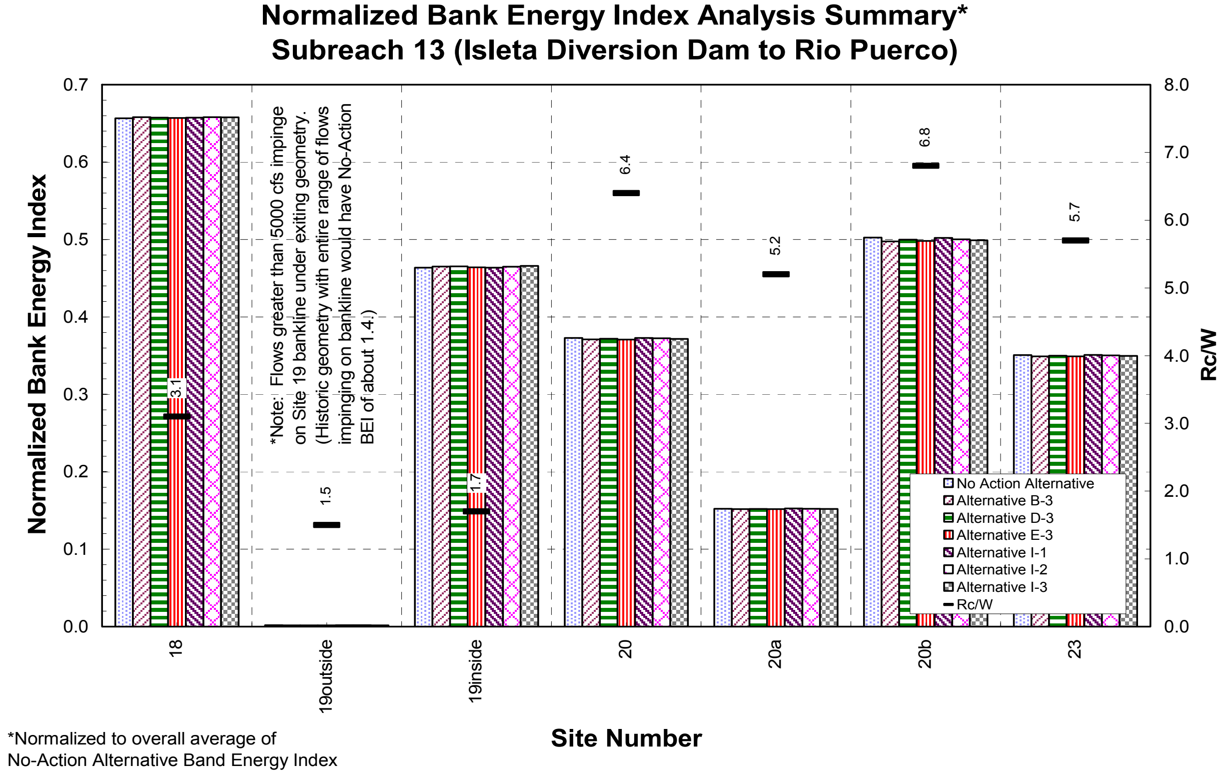

Figure H-4.9b Percent change in BEI values over the No-Action Alternative for selected sites in Subreach 12.

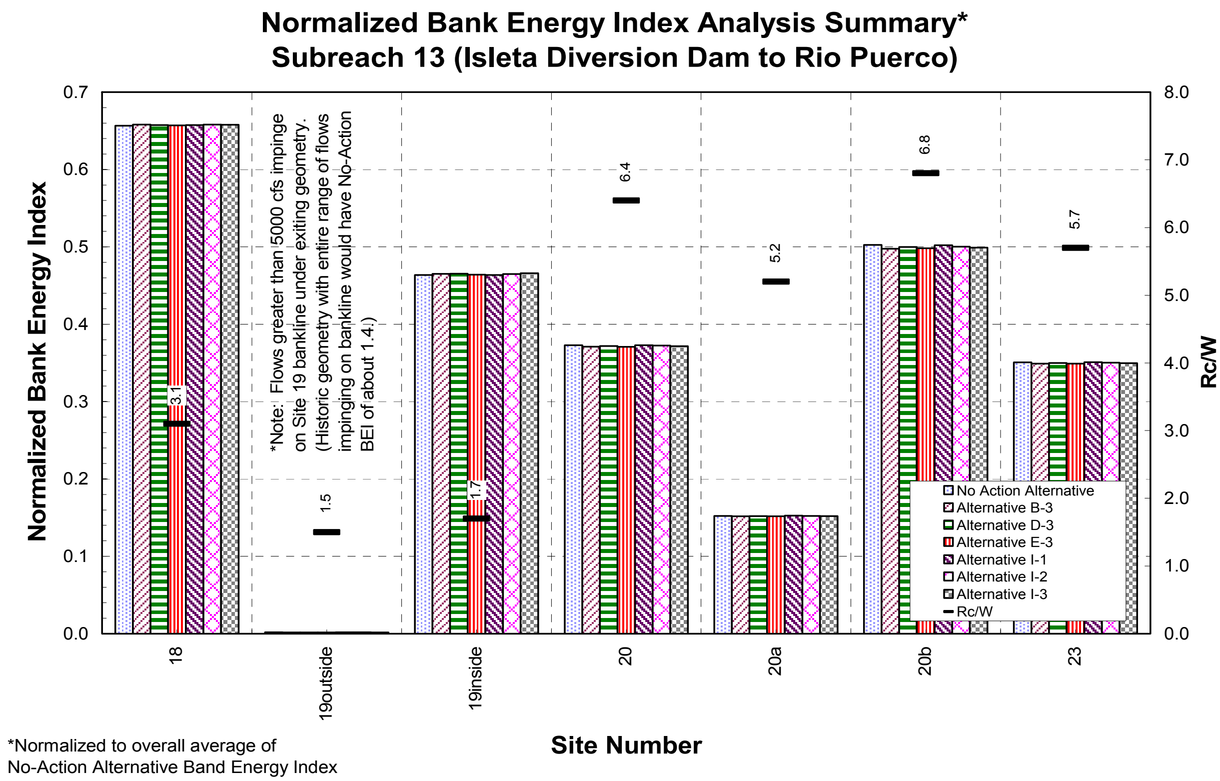

Figure H-4.10a Normalized BEI values for the selected sites in Subreach 13.

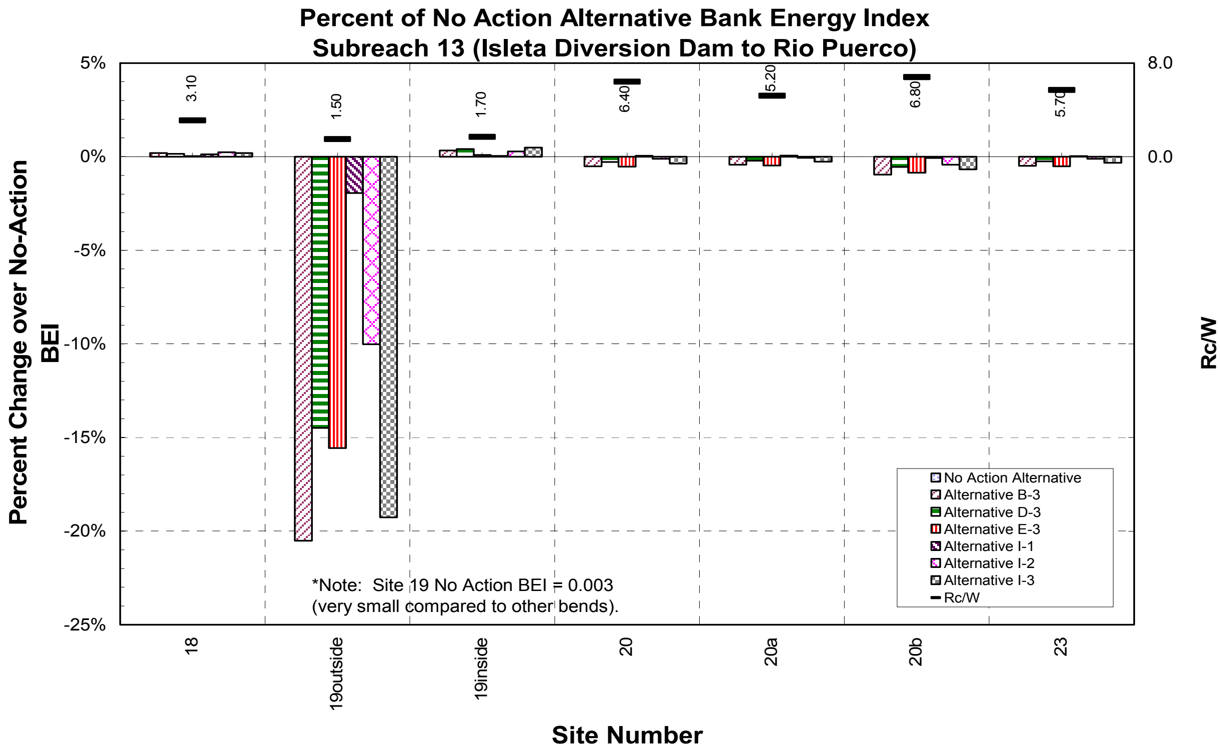

Figure 4.10b Percent change in BEI values over the No-Action Alternative for selected sites in Subreach 13.

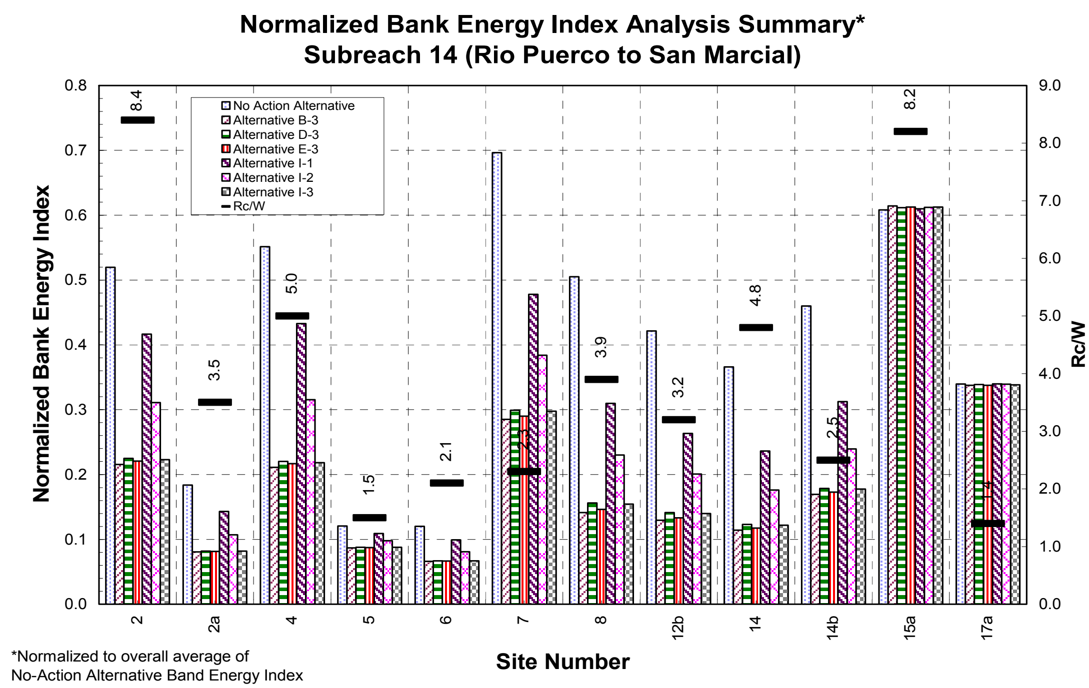

Figure H-4.11a Normalized BEI values for the selected sites in Subreach 14.

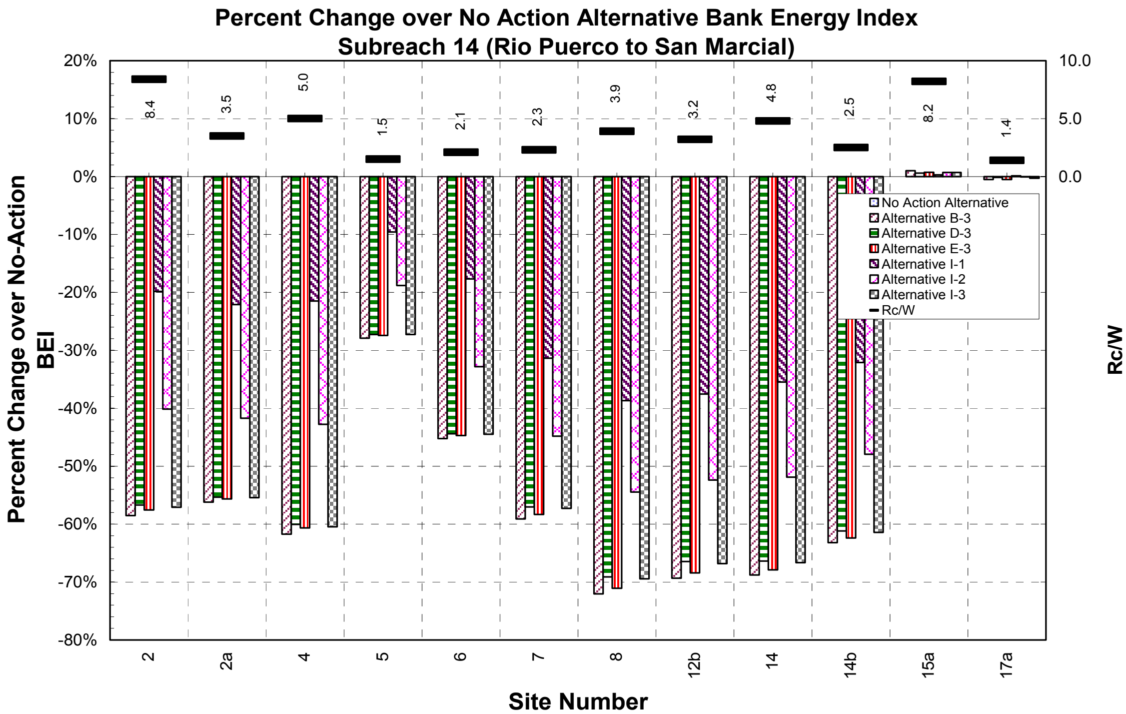

Figure H-4.11b Percent change in BEI values over the No-Action Alternative for selected sites in Subreach 14.

Figure H-4.7 through **Figure H-4.10** indicate that, although there is significant variability in the BEI from site to site, there is very little change among the alternatives at a given site in the portion of the reach upstream from San Acacia. Except at Site 19 (outer bank surface), the change in BEI over the No-Action Alternative is less than about 1 percent in Subreaches 10a through 14a, and is less than about 5 percent in Subreach 7. Because the BEI value computed for the outside bank surface at Site 19 is based on the infrequent, high-magnitude discharges above 4,500 cfs, the total energy expended on the bank is relatively small. As a result, a small change in the frequency of discharges above 4,500 cfs associated with the action alternatives will significantly change the amount of energy expended on the bank, but this change will likely have very little effect on the erosion of the outside bank. In Subreach 7, the change from the No-Action Alternative to Alternatives B-3 and D-3 is somewhat larger than at the other sites because high discharges are maintained for longer time periods, resulting in larger bend shear stresses.

In Subreaches 14c and 14d, below San Acacia, the normalized BEI values are significantly lower under the Action Alternatives than under the No-Action Alternative due to the reduction in discharge caused by diversions into the Low Flow Conveyance Channel (LFCC). The reduction in BEI values from the No-Action Alternative (**Figure H-4.9b**) ranges from as little as 12 percent at Site 5 under Alternative I-1 to as much as 72 percent at Site 8 under Alternative B-3. At all of the sites evaluated downstream of San Acacia, the largest percentage reduction in BEI values is associated with Alternative B-3, since this alternative diverts the highest volume of flow to the LFCC, which reduces the frequency of the moderate to high discharges that expend the most energy on the banks. The smallest reduction in BEI values is associated with Alternative I-1, since this alternative diverts the lowest volume of flow to the LFCC.

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APPPENDIX A — Width Variability of Subreaches

Width variability within short subreaches is presented in the following graphs. The graphs are similar to **Figure 3-11, Figure 3-17 and Figure 3-19** in the main text where the top line is maximum width and bottom line is minimum width. Central dark area is the central 50% of width values. The center dotted line is the mean width of the subreach.

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APPENDIX I
WATER OPERATIONS

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List of Tables

1.0 INTRODUCTION

This appendix describes the support provided by the Water Operations Team to the Upper Rio Grande Water Operations Review EIS. The Water Operations Team was composed of representatives of each of the three joint lead agencies and also included representatives of other agencies/entities participating in the development of the EIS. The Water Operations Team functioned as a support team, and did not represent any particular resource impacted by water operations. Rather, the Water Operations Team provided expertise regarding water operations at the various facilities under evaluation and assisted in the identification and evaluation of the alternatives, from a water operations perspective. Following the selection of alternatives, the Water Operations Team conducted modeling analyses and distributed model results to profile some of the differences between the alternatives. Model results were distributed to the resource teams for their use in analyzing impacts of operations alternatives on their resource of interest.

This appendix provides supporting information regarding the work conducted by the Water Operations Team. The information contained herein provides additional detail concerning the development and initial screening of alternatives, water operations modeling, and rating of the alternatives from a water operations perspective.

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2.0 OBJECTIVES

The Water Operations Team served to meet specific objectives in support of the Water Operations Review. These objectives included:

a) Provide a description of the existing conditions and regulatory framework for the projects and facilities in the study area;

b) Provide support to resource teams in understanding system flexibilities and limitations;

c) Identify flexibilities that could be used as a basis for articulating alternative actions;

d) Assess actions consistent with flexibilities and identify consistency with the Purpose and Need of this EIS and to identify fatal flaws of particular actions;

e) Group actions for facilities with identified flexibilities into preliminary alternatives;

f) Rate preliminary alternatives on the basis of engineering judgment, water operations and facility knowledge and preliminary model results;

g) Provide recommendations to the Interdisciplinary Team, based on preliminary screening analysis, for a short list of alternatives for detailed analysis;

h) Conduct simulations using the Upper Rio Grande Water Operations Model (URGWOM)[2] to illustrate some of the hydrologic differences among the identified alternatives;

i) Develop simplifying model input assumptions for the planning period;

j) Develop a 40-year synthetic sequence of hydrology to drive the planning model, for purposes of comparative analysis of alternatives;

k) Provide model results and other supporting analyses to the resource teams;

l) Assess the advantages and disadvantages of the alternatives from a water operations perspective.

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3.0 DESCRIPTION OF FACILITIES

3.1 Projects and Facilities in Colorado

Closed Basin Project: Located near Alamosa, Colorado, the Bureau of Reclamation (Reclamation) designed the Closed Basin Project to produce 600,000 acre-feet of groundwater from wells, in any ten-year period, to help Colorado meet downstream delivery obligations. Up to 5,300 acre-feet of that water may be used for wildlife habitat and deliveries to the river must be in accordance with the Clean Water Act. There may be no more than two feet of drawdown to the water table permitted in specified areas. Well degradation is presently limiting the annual production to approximately 25,000 acre-feet per year.

Platoro Dam: Platoro Dam, on the Conejos River, is a Reclamation facility operated by the Conejos Water Conservancy District. It was constructed in 1952 for irrigation and flood control and has an allocation of 54,000 acre-feet for irrigation and as well as serving as a temporary control for spring flooding events from snowmelt and rainfall (joint-use-pool). An additional 6,000 acre-feet is allocated exclusively to provide flood control on the Conejos River in Colorado and the Rio Grande in both Colorado and New Mexico. If flood space is needed, water in the conservation pool is released to make room. A 3,000 acre-foot pool is maintained for recreation, fish, and wildlife, and the reservoir is also managed to preserve fish and wildlife habitat downstream.

Procedures used in the flood control regulation of Platoro Reservoir are in accordance with part 208, Flood Control Regulation, Platoro Dam and Reservoir, Conejos River, Colorado, as published in the Federal Register. The operation of Platoro Reservoir for flood control involves communication and coordination between the State of Colorado, Division of Water Resources; Alamosa, Colorado; Conejos Water Conservancy District; and the US Army Corps of Engineers (Corps). The State of Colorado has the responsibility for the administration of water rights on the Conejos River and communication with the Corps on flood control problems on the Conejos River. The Corps has the responsibility for determining the flood control operation of Platoro. Pertinent elevation data is shown below. Additional information regarding this reservoir is provided in the Platoro Dam and Reservoir Water Control Manual[3].

Platoro Dam

	Elevation (feet)	Area (acres)	Capacity (acre-feet)
Top of dam:	10,048.00	1,012	73,291
Maximum pool:	10,042.00	985	67,301
Total storage at spillway crest:	10,034.00	948	59,571
Top of conservation pool	10,027.57	917	53,571

3.2 Reservoirs on the Rio Chama

Three reservoirs, Heron, El Vado, and Abiquiu, were constructed on the Rio Chama and its tributaries to store water for flood control and water supply. Hydroelectric power plants are located at El Vado Dam and Abiquiu Dam, which are operated as “run-of-the-river” plants – that is, the demand for water release for hydroelectric power at these dams is subservient to other demands. Operations of El Vado are not within the scope of this EIS, but descriptive information concerning this reservoir and its operations are included below for informational purposes.

Heron Reservoir: Heron Reservoir stores and releases water imported from the San Juan River Basin and is the primary storage feature of the San Juan-Chama Project. Owned and operated by Reclamation, Heron Reservoir’s entire capacity of about 401,300 acre-feet is dedicated to storing San Juan-Chama

Project water. All native Rio Grande inflow to Heron Reservoir is bypassed. The water imported to the Rio Grande Basin from the San Juan River Basin provides supplemental water supplies for various communities and irrigation districts. The project also provides fish and wildlife habitat as well as recreational opportunities. An average of 91,210 acre-feet per year of the firm yield is allocated annually by contract or project authorization; the remaining 4,990 acre-feet is as yet uncontracted.

Three basic principles control the water release schedule for Heron Reservoir. The first states that no Rio Grande water is to be stored in Heron; all natural inflow is bypassed. The second principle states that water is released from Heron only to individual Project contractors for storage in downstream reservoirs or for the irrigation consumption or offset of groundwater pumping depletions on the Rio Grande. These depletions are offset by releases of San Juan-Chama water from Heron Reservoir and ensure no residual effects to natural waters of the Rio Grande.

The third principle states that San Juan-Chama contractors are not allowed to carryover their annual allocations into the next calendar year. Contracted water not called for by December 31 remains in Heron Reservoir as part of project supply and no longer belongs to the individual contractor. In the past, Reclamation negotiated temporary waivers with contractors that allow carryover until April 30 in order to provide release rates on the Rio Chama that enhance the fishery between El Vado and Abiquiu Reservoirs during the winter and provide flexibility in managing river flows.

Pertinent elevation data is shown below. Additional information is provided in the Heron Reservoir Standing Operating Procedures[4].

Heron Reservoir

	Elevation (feet)	Area (acres)	Capacity (acre-feet)
Top of dam:	7,199.00	6,600	475,000
Maximum pool:	7,190.80	6,148	429,657
Total storage at spillway crest:	7,186.10	5,906	401,334
Top of dead pool:	7,003.00	106	1,218

El Vado Reservoir: El Vado Dam was originally constructed to provide conservation storage for a supplemental irrigation supply for MRGCD lands along the Rio Grande from Cochiti Reservoir to below Socorro, New Mexico. Because El Vado Dam was constructed after 1929 (completed in 1935), operation of the reservoir for storage and release of Rio Grande water is subject to the Rio Grande Compact. Water imported into the Rio Grande Basin through the San Juan-Chama Project and stored in El Vado Reservoir is not subject to the storage and release restrictions of the Rio Grande Compact. Pertinent elevation data is shown below. Additional information is available in the El Vado Reservoir Standing Operating Procedures[5].

El Vado Reservoir

	Elevation (feet)	Area (acres)	Capacity (acre-feet)
Top of dam:	6,914.50	3,620	232,500
Maximum pool:	6,908.00	3,418	206,205
Total active conservation storage:	6,902.00	3,232	186,252
Total storage at spillway crest:	6,879.00	2,454	120,544
Top of dead pool:	6,775.00	84	480

With respect to native water, El Vado Reservoir stores natural inflow that exceeds current Middle Rio Grande Conservancy District (MRGCD) and other needs below El Vado Dam. The major storage season is during spring runoff and storage can then be released during the irrigation season to users in the Middle Rio Grande Valley as needed.

Article VII of the Rio Grande Compact provides that no Rio Grande water in El Vado Reservoir can be stored when usable water in project storage (storage in Elephant Butte and Caballo Reservoirs) is less than 400,000 acre-feet. Article VI provides that any Rio Grande water stored in El Vado Reservoir must be held in storage to the extent of New Mexico's accrued debit under the compact.

El Vado is operated to store native water for the six Middle Rio Grande Pueblos of Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, and Isleta. The Bureau of Indian Affairs (BIA) and Reclamation compute the amount of storage required, and Indian storage water is released only when the natural flow of the Rio Grande is insufficient to adequately supply irrigation to 8,847 acres of Indian lands.

No native water can be stored in El Vado Reservoir when doing so would deprive acequias along the Rio Chama downstream from El Vado of water to which they are entitled. In 1971, the New Mexico State Engineer required that El Vado Reservoir be operated during the irrigation season to pass all natural flow of the Rio Chama up to 100 cfs, as measured below Abiquiu Dam, during the irrigation season.

El Vado Reservoir operation is affected by the San Juan-Chama Project in two ways. First, San Juan-Chama Project water released from Heron Dam for use downstream of El Vado Reservoir is simply passed through. Secondly, large volumes of San Juan-Chama Project water in El Vado Reservoir may be stored for extended periods of time. The MRGCD has contracted for 20,900 acre-feet per year of San Juan-Chama Project water and maintains as much of this water in El Vado Reservoir as conditions permit. In addition, the MRGCD has contracted with various contractors of San Juan-Chama Project water to allow for storage of their water in El Vado Reservoir.

Abiquiu Dam and Reservoir: Abiquiu Reservoir is owned and operated by the Corps. Abiquiu Dam and Reservoir are operated for flood and sediment control in accordance with conditions and limitations stipulated in the Flood Control Act of 1960 (P.L. 86-645). Reservoir regulation for flood control is also coordinated with the operation of Jemez Canyon, Cochiti, and Galisteo Reservoirs. Abiquiu Reservoir is operated to limit flow in the Rio Chama, insofar as possible, to the downstream channel capacities of 1,800 cfs for the reach below Abiquiu Dam; 3,000 cfs for the reach below the Rio Chama at Chamita stream gage; and, on the Rio Grande main stem, 10,000 cfs for the reach below the Rio Grande at Otowi stream gage.

These channel capacity restrictions result in temporary storage of Rio Grande floodwater, which is then evacuated as quickly as downstream channel conditions allow, unless and until the conditions imposed by P.L. 86-645 are triggered. When P.L. 86-645 is triggered, Abiquiu Reservoir retains carryover flood storage because no Rio Grande water may be withdrawn from storage after July 1 at the natural flow (that is--exclusive of water released from storage upstream) at the Otowi gage is less than 1,500 cfs. Rio Grande water that is locked in must remain in storage until the end of the irrigation season (November 1). Flood storage that is retained throughout the summer is released after November 1 and must be fully evacuated by March 31 of the following year. Depending on the volume of water from spring runoff, Abiquiu Reservoir has either been able to safely pass inflow without any carryover or has locked in as little as 3,500 acre-feet in 1994 to as much as 215,000 acre-feet in 1987. Pertinent elevation data is shown below. Additional information can be found in the Abiquiu Reservoir Water Control Manual[6].

Abiquiu Reservoir

	Elevation (feet)	Area (acres)	Capacity (acre-feet)
Top of dam:	6,381.00	16,480	1,639,800
Maximum pool:	6,374.70	15,536	1,535,300
Total storage at spillway crest:	6,350.00	15,580	1,192,800
Top of flood-control pool:	6,283.50	7,439	545,783
Top of San Juan-Chama storage:	6,220.00	4,029	183,882
Top of dead pool:	6,077.00	--	--

In 1981, P.L. 97-140 authorized the storage of 200,000 acre-feet of San Juan-Chama water in Abiquiu Reservoir. The City of Albuquerque has obtained a storage easement to an elevation of 6,220 feet. Real estate interests have not been obtained above elevation 6,220 feet to accommodate the full 200,000 acre-feet as authorized. San Juan-Chama capacity is annually reduced because of the estimated sediment deposition into the reservoir. San Juan-Chama storage is held below an elevation of 6,220 feet and released as requested by the storage contractors. The San Juan-Chama pool also serves to increase sediment trap efficiency and enhance recreational opportunities as well as fish and wildlife habitat at the reservoir.

3.3 Reservoirs in the Middle Valley

Three reservoirs were constructed on the Rio Grande in the Middle Valley for flood and sediment control. The projects are Cochiti Dam and Lake, Galisteo Dam and Jemez Canyon Dam and Reservoir.

Cochiti Dam and Lake: Cochiti Lake is owned and operated by the Corps in coordination with other Corps projects in the basin. Cochiti Lake has maintained a permanent recreation pool of approximately 50,000 acre-feet since the dam was completed. The permanent pool, which includes an intermittent pond in the arm of the Santa Fe River, provides sediment-control benefits that trap approximately 1,000 acre-feet of sediment per year. The permanent pool was established and is maintained by San Juan-Chama Project water. The remaining capacity of the reservoir, totaling about 545,000 acre-feet, is reserved for flood and sediment control.

Cochiti Dam is operated to bypass all inflow to the lake, to the extent that downstream channel conditions are capable of safely bypassing the flow. Flood-control operations are initiated when inflow to the lake is in excess of the downstream channel capacity. Stored floodwaters are retained in the reservoir and held until downstream channel conditions allow for its release, provided that, after July 1, the natural inflow is 1,500 cfs or and a minimum of 212,000 acre-feet of storage is available in Cochiti Reservoir to control summer flood flows. Flood storage that is "locked in" is released beginning November 1 (see discussion under carryover storage at Abiquiu Reservoir). Pertinent elevation data is shown below. Additional information can be found in the Cochiti Lake Water Control Manual[7].

Cochiti Lake

	Elevation (feet)	**Area (acres)**	**Total capacity (acre-feet)**
Top of dam:	5,479.00	11,176	771,719
Maximum pool:	5,474.10	10,636	718,019
Total storage at spillway crest:	5,460.50	9,307	582,019
Permanent pool (varies): 5,340.1 F	5,335.92	1,200	49,359
Conduit invert:	5,255.00	0	0

P.L. 88-293 authorized the release of 50,000 acre-feet of San Juan-Chama Project water for the initial filling of a permanent pool of 1,200 acres in Cochiti Lake and thereafter sufficient water annually to offset evaporation from such areas. A portion of the release of San Juan-Chama Project water is used to offset evaporation loss from the water surface of a small wetland on the Santa Fe River above Cochiti Dam.

Jemez Canyon Reservoir: Jemez Canyon Dam and Reservoir is owned and operated by the Corps. Jemez Canyon Dam and Reservoir were authorized by the Flood Control Act of 1948 and are operated in tandem with Cochiti Reservoir to control flows through the Middle Rio Grande Valley. Flood storage, if any, is accumulated atop the sediment-control pool and released as soon as possible thereafter. Jemez Canyon Dam is currently operated as a dry reservoir. Pertinent elevation data is shown below. Additional information can be found in the Jemez Canyon Dam and Reservoir Water Control Manual[8].

Jemez Canyon Dam

	Elevation (feet)	Area (acres)	Total capacity (acre-feet)
Top of embankment:	5,271.6	5,320	260,723
Maximum pool:	5,271.2	5,300	259,423
Total storage at spillway crest:	5,232.0	2,943	97,425
Sediment retention pool:	5,196.7	1,364	25,517
Zero storage:	5,154.0	0	0

3.4 Reservoirs in the Lower Valley

Two reservoirs were constructed on the Rio Grande in the Lower Valley as part of the Rio Grande Project: Elephant Butte Reservoir and Caballo Reservoir. Elephant Butte Reservoir is authorized to operate for conservation storage and generation of hydroelectric power. Caballo Reservoir is operated for conservation storage and flood control.

Elephant Butte Reservoir: Elephant Butte Reservoir is owned and operated by Reclamation, and is the principal water storage facility for 178,000 irrigated acres of the Rio Grande Project in south-central New Mexico and west Texas. The reservoir is operated to maintain a 25,000 acre-foot pool vacant for flood-control purposes in the winter months and 50,000 acre-foot pool for flood control in the summer months. A 50,000 acre-foot minimum recreation pool is authorized and maintained with San Juan-Chama Project water, when available. Elephant Butte Reservoir is also operated to ensure that the U.S. 1906 Treaty obligation with Mexico to deliver 60,000 acre-feet per year at the Acequia Madre headgate in Mexico can be met. Pertinent elevation data is shown below. Additional information can be found in the Elephant Butte Standing Operating Procedures[9].

Elephant Butte Dam and Reservoir

	Elevation (feet)	Area (acres)	Total capacity (acre-feet)
Top of dam:	4,414.0	39,918	2,289,017
Maximum pool:	4,410.0	37,670	2,133,841
Total storage at spillway crest:	4,407.0	35,984	2,023,400
Inactive:	4,231.5	0	0

In 1981, Congress authorized the Secretary of the Interior to enter into contracts for storage of San Juan-Chama Project water in Elephant Butte Reservoir. P.L. 97-140 provides that the amount of evaporation loss and spill chargeable to San Juan-Chama Project water shall be accounted for under procedures established by the Rio Grande Compact Commission. San Juan-Chama Project water may also be stored in Elephant Butte Reservoir for recreational purposes.

Caballo Reservoir: Caballo Dam and Reservoir is operated for conservation storage purposes by Reclamation and for flood-control purposes by the U.S. Section of the International Boundary and Water Commission (IBWC). Completed in 1938, Caballo Dam provides flood protection for the El Paso/Juarez area by the reservation of 100,000 acre-feet of total capacity for a dedicated flood-control pool, which is under the jurisdiction of IBWC. The reservoir also serves to re-regulate releases made from Elephant Butte Reservoir for the generation of hydroelectric power.

Caballo Dam and Reservoir

	Elevation (feet)	Area (acres)	Total capacity (acre-feet)
Top of dam:	4,190.00	13,250	425,000
Total storage at spillway crest:	4,182.00	11,532	326,672
Top of conservation storage pool:	4,172.44	9,352	226,629
Top of dead storage:	4,104.0	0	0

4.0 OPERATIONAL FLEXIBILITIES AND GENERAL DESCRIPTIONS OF ALTERNATIVE ACTIONS

Operational flexibilities at facilities and within the river system were identified with consideration to existing authorizations through internal analysis and in public scoping meetings. Within the identified flexibilities, a range of actions were identified to be considered elements of alternative operating plans. These actions include: waivers for Contractor water from Heron Reservoir, conservation storage amounts in Abiquiu Dam, altering channel capacity downstream of Abiquiu Dam and Cochiti Dam, using the Low Flow Conveyance Channel for water diversions and enhancing communication and coordination protocols. No-Action scenarios were also developed. A wide range of specific actions within the flexibility were identified and then screened in consideration of the EIS Purpose and Needs Statement. This gives a general overview of these flexibilities and the next section develops specific actions within the identified alternatives.

Heron Waivers -- A waiver is a temporary relief of the requirement for contractors to take delivery of a current year San Juan-Chama (SJC) allocation before December 31 of the same year. Waivers came into existence when high discharge rates in December were determined to be detrimental to the trout fishery within the Wild and Scenic Reach of the Rio Chama. On November 3, 1983, Mr. Emmet Rice, Reclamation field solicitor, gave an opinion that SJC contractors could request a waiver from Reclamation to extend their water delivery date. A key point to Rice's opinion is that waivers "inure to the benefit of the United States to effect orderly project operations and do not inure to the benefit of any water user" (US Dept. of Interior, 1983).

In the past, temporary waivers have been used to enhance winter flows and fisheries management on the Rio Chama. Waivers generally would allow SJC water to remain in Heron Reservoir through April 30 of a particular year, but this date could be extended even further. This date has been extended in the past, but only under extreme circumstances. Currently, SJC water contractors must take deliver of contracted water in storage at Heron Reservoir by the end of the year, either by use, sale, or by contracts for storage elsewhere. The proposed alternatives in the EIS extend the waiver date. Extending the waiver date could allow for additional storage of native water downstream at El Vado and Abiquiu Reservoirs. There are certain conditions that have to be met to allow this to happen. Projected snowmelt runoff into Heron Reservoir would not impact Reclamation's ability to maximize diversions of SJC water. In other words diversion of SJC water would not be impacted. Another requirement would be that New Mexico must be in compliance with the Rio Grande Compact.

Conservation Storage – The proposed action is storage of native flows in Abiquiu Reservoir during the spring runoff period. Storage at Abiquiu Reservoir would be limited by the amount of storage available that is not being used for San Juan-Chama water. The water would be stored when native flows exceed downstream demands and when New Mexico is in compliance with the Rio Grande Compact. The available amount of runoff and the total volume of SJC water in the reservoir would also limit storage and Conservation storage (native water) and SJC water storage, shall not exceed elevation 6220.0 ft. In order to store conservation water the Abiquiu Reservoir release rate would be limited to 200 cfs respectively during the time when excess flows are being stored. The release rate would be increased to meet demand if needed but would not drop below the target rate (200 cfs). The proposed alternatives explore a range of options for storage of native Rio Grande water. The options include storing 20,000, 75,000, and 180,000 acre-feet of native water.

Channel Capacity -- The proposed alternatives explore changes in channel capacity downstream from Abiquiu and Cochiti Dams. The options included decreases and increases in the release rates.

Low Flow Conveyance Channel (LFCC) – The LFCC was designed to increase conveyance and compact deliveries to Elephant Butte Reservoir by minimizing losses from evaporation, transpiration and infiltration. While diversions at San Acacia into the LFCC are not presently occurring, flows do occur in the LFCC through irrigation return and ground water seepage. Flows from ground water influx and drainage increase in the downstream direction. The proposed alternatives offer a range of operations. At one end, no diversions would be made from the river to the LFCC at San Acacia. Other options involve diverting 500, 1,000, and 2,000 cfs while maintaining a minimum bypass of 250 cfs in the river at San Acacia.

Communication and Coordination Protocol - Protocols to improve inter-agency processes within agencies and within the public have been developed and are provided in Attachment B. These protocols are common to all alternatives.

5.0 DEVELOPMENT OF ALTERNATIVES

This preliminary screening analysis is provided in detail in Attachment A. The table in Attachment A shows the actions under consideration, the water operations attribute used to evaluate each action and the rationale for determining whether or not each action could be maintained (or eliminated due to the presence of a fatal flaw), according to various attributes of the actions. The following discussion provides a reason why some actions moved forward, while others were dropped from consideration.

5.1 Heron Waivers

The use of waivers is appropriate for specific operational purposes, which “inure to the benefit of the United States” and not specifically to the benefit of contractors, even though contractors may benefit from the waiver. The use of waivers must never adversely impact Reclamation’s ability to maximize diversions of SJC water. Various actions utilizing different dates for Heron waiver are summarized below, with comments derived from the initial screening process.

5.1.1 No waivers

The Water Operations Team reviewed the impacts of requiring all SJC contractor water to be released by December 31 of the same year in which it is allocated, essentially eliminating Reclamation’s current operational flexibility to issue waivers for carryover storage into the following year. This option was eliminated because Reclamation currently has the flexibility to require contractors to take their allocation by December 31, or issue carryover waivers if it is of benefit to the United States. The “no waiver” option removes operational flexibility, which is contrary to the goals of Water Operations Review. This action would essentially impact winter flows on the Rio Chama between El Vado Dam and Abiquiu Reservoir in January and February. The flows released during this time would be limited to movement of the Cochiti Lake evaporation replacement water and whatever bypass of native flows there is. The evaporation replacement water for Cochiti Lake (5,000 acre-feet) is normally moved between November and February. Essentially with this type of operation the flows on the Rio Chama between El Vado Dam and Abiquiu Reservoir would be high during November and December and then drop to below 50 cfs during January and February. Another reason this action was eliminated is that contractors that do not take delivery of contracted water in storage at Heron Reservoir either by use, contracting for storage space elsewhere, or sale, would forfeit their allocation which would revert back to project storage.

5.1.2 No change (flexibility to issue waivers through April 30)

The Water Operations Team reviewed the feasibility of Reclamation retaining its current operational flexibility to issue waivers to SJC contractors for the carryover storage of their allocation in Heron Reservoir through April 30 of the following year. This option was retained for additional analysis because it essentially represents the “no change” alternative, and provides operational flexibility to the benefit of the United States. This action allows flexible water management that benefits the SJC contractors and provides for winter flows on the Rio Chama between El Vado Dam and Abiquiu Reservoir.

5.1.3 Flexibility to issue waivers through June 30

The Water Operations Team reviewed the feasibility of Reclamation expanding its current operational flexibility to issue waivers to SJC contractors by extending the carryover storage deadline to June 30 of the following year, if this action would prove beneficial to the United States. This option was eliminated from additional analysis because it was not seen to provide any significant benefits over the current practice of Reclamation’s flexibility to offer waivers through April 30. The main objective with this action is to create additional space in El Vado Reservoir and Abiquiu Reservoir for the storage of native water by holding SJC water in Heron Reservoir and delivering it at a later date. This action was eliminated because it allows only temporary space for additional storage of native water in El Vado Reservoir or Abiquiu Reservoir. SJC water would be delivered during the snowmelt runoff season and any native water stored during the March–May time frame would have to be evacuated to make space for the SJC water. The native water stored during the March-May time frame in most years could not be used because the Rio Chama and the main stem of the Rio Grande would provide enough water to meet all needs downstream from the reservoirs.

5.1.4 Flexibility to issue waivers through August 31

The Water Operations Team reviewed the feasibility of Reclamation expanding its current operational flexibility to issue waivers to SJC contractors by extending the carryover storage deadline to August 31 of the following year, if this action would prove beneficial to the United States. This option was retained for additional analysis because it has the potential to enhance the operational flexibility of the system for benefit of the United States. The operational flexibility to modify storage plans in downstream reservoirs could be enhanced by extending the waiver date to August 31. The main objective with this action is to create additional space in El Vado Reservoir and Abiquiu Reservoir for the storage of native water by holding SJC water in Heron Reservoir and delivering it at a later date. This action was retained because it allows for temporary space for additional storage of native water in El Vado Reservoir or Abiquiu Reservoir. SJC water would be delivered after the snowmelt runoff season in July and August. In most years, there is a call for native water out of storage in late June to meet downstream demands. The native water released from storage would then be replaced by a release of SJC water out of Heron Reservoir.

5.1.5 Flexibility to issue waivers through September 30

The Water Operations Team reviewed the feasibility of Reclamation expanding its current operational flexibility to issue waivers to SJC contractors by extending the carryover storage deadline to September 30 of the following year, if this action would prove beneficial to the United States. This option was retained for additional analysis because it has the potential to enhance the operational flexibility of the system for benefit of the United States. The operational flexibility to modify storage plans in downstream reservoirs could be enhanced by extending the waiver date to September 30. The main objective with this action is to create additional space in El Vado Reservoir and Abiquiu Reservoir for the storage of native water by holding SJC water in Heron Reservoir and delivering it at a later date. This action was retained because it allows for temporary space for additional storage of native water in El Vado Reservoir or Abiquiu Reservoir. SJC water would be delivered after the snowmelt runoff season in July and August. In most years, there is a call for native water out of storage in late June to meet downstream demands. The native water released from storage would then be replaced by a release of SJC water out of Heron Reservoir. Additional month would provide more flexibility.

5.2 Abiquiu – Conservation Storage

The Water Operations Team looked at the feasibility of storing native water in Abiquiu Dam in various amounts, ranging from 20,000 acre-feet to 200,000 acre-feet. The proposed action is for storage of native flows in Abiquiu Reservoir during the spring runoff period. Storage at Abiquiu Reservoir would be limited by the amount of storage available that is not being used for San Juan-Chama water. The water would be stored when native flows exceed downstream demands and when New Mexico is in compliance with the Rio Grande Compact. The available amount of runoff and the total volume of SJC water in storage would also limit the amount of conservation storage (native water) that could take place. The storage of SJC water and conservation water cannot exceed elevation 6,220.0 ft. In order to store conservation water in Abiquiu Reservoir the release rate below the dam would be limited to 200 cfs respectively during the time when excess flows are being stored. The release rate would be increased to meet demand if needed but would not drop below the target rate (200 cfs).

Initial assessments of the feasibility of these actions indicated that storage in the amounts of 20,000, 50,000, and 100,000 were feasible assuming that the space was not needed for SJC storage. Storage in the amount of 200,000 acre-feet, on the other hand, appears infeasible, based on the fact that storage is presently limited to 183,000 acre-feet. Storage easements would need to be purchased in order to store the additional 17,000 acre-feet. This storage amount is depleted by sediment every year. URGWOM will be used to better understand under what conditions and how often storage in the various amounts can take place. Attachment A, Evaluation of Draft Alternatives, shows other considerations used in the analysis.

5.3 Abiquiu Channel Capacity

The Water Operations Team looked at feasibility of changing the channel capacity downstream from Abiquiu Dam. The options the team explored included decreases and increases in release rates. This section explores release rates ranging from 600 cfs to 2,500 cfs. Additional information regarding the alternatives can be found in **Attachment A**.

5.3.1 600 cfs channel capacity

The Water Operations Team looked at the feasibility of the channel capacity below Abiquiu Dam being lowered to 600 cfs. It became apparent during the preliminary analysis that it was not feasible to have such a low channel capacity. The decision to discard this action was based on the following: compact deliveries could not be met, irrigation demand through the middle valley would not be met, ESA deliveries could not be bypassed, and City of Albuquerque San Juan-Chama water could not be delivered. Abiquiu is operated to bypass the natural flow first; therefore, it would be extremely difficult to release SJC water.

5.3.2 800 cfs channel capacity

The Water Operations Team looked at the feasibility of the channel capacity below Abiquiu Dam being lowered to 800 cfs. It became apparent during the preliminary analysis that it was not feasible to have such a low channel capacity. The decision to discard this alternative was based on the following: compact deliveries could not be met, irrigation demand through the middle valley would not be met, ESA deliveries could not be bypassed, City of Albuquerque San Juan-Chama water could not be delivered, etc. While the increased channel capacity helped some, it was not enough to allow releases to meet the needs downstream. Abiquiu is operated to bypass the natural flow first; therefore, it would be difficult to release SJC water during the irrigation season. There would be no way to meet irrigation demand, domestic demand and endangered species flows with this type of release.

5.3.3 1,200, 1,500, 1,800, 2,000 cfs channel capacity

The Water Operations Team looked at the feasibility of the channel capacity below Abiquiu Dam in the range to the following increments: 1,200, 1,500, 1,800 and 2,000 cfs. It became apparent during the preliminary analysis that a more in-depth analysis would be needed to determine the most feasible channel capacity. The URGWOM along with Flo-2D and other resource models was used to determine the most feasible channel capacity. Attachment A: Evaluation of Draft Alternatives shows other considerations used in the preliminary analysis.

5.3.4 2,500 cfs channel capacity

The Water Operations Team looked at the feasibility of the channel capacity below Abiquiu Dam being increased to 2,500 cfs. It became apparent during the preliminary analysis that it was not feasible to have such a high channel capacity. The decision to discard this alternative was based on the following: there would be an increase in overbank flooding, more bank erosion, and the fact that most diversion structures on the Rio Chama are made of rock and brush. While the increased channel capacity would help in compact deliveries, overbank flooding and increased flood protection in the Middle Rio Grande Valley, the negative impacts eliminated this alternative.

5.4 Cochiti Channel Capacity

The Water Operations Team looked at feasibility of changing the channel capacity downstream from Cochiti Dam. The options the team explored included decreases and increases in release rates. Additional information regarding the alternatives can be found in Attachment A.

5.4.1 5,000 channel capacity

The Water Operations Team looked at the feasibility of the channel capacity below Cochiti Dam being lowered to 5,000 cfs. It became apparent during the preliminary analysis that it was not feasible to have such a low channel capacity. The decision to discard this alternative was based on the following: it would impact compact deliveries, increase the chances for carryover storage in Abiquiu and Cochiti, provided no channel forming discharges, decreased flood protection, decreased overbank flooding, and the City of Albuquerque would not be able to take delivery of SJC water during snowmelt runoff. Cochiti Dam is primarily operated to bypass the natural flow; therefore it would be difficult to release SJC water during snowmelt runoff in some years.

5.4.2 7,000, 8,000, 9,000, 10,000 cfs channel capacity

The Water Operations Team looked at the feasibility of the channel capacity below Abiquiu Dam in a capacity ranging from 7,000 to 10,000 cfs. It became apparent during the preliminary analysis that a more in-depth analysis would be needed to determine the most feasible channel capacity. URGWOM, along with Flo-2D and other resource models will be used to determine the most feasible channel capacity.

5.4.3 12,500 cfs channel capacity

The Water Operations Team looked at the feasibility of the channel capacity below Cochiti Dam being increased to 12,500 cfs. It became apparent during the preliminary analysis that it was not feasible to have such a high channel capacity. The decision to discard this alternative was based on following: increase in bank sloughing, possible flooding of irrigation land in the reach extending from Cochiti to Bernalillo, and the effect high flows would have on bank protection. While the increased channel capacity would help in compact deliveries, overbank flooding, and increased flood protection in the Middle Rio Grande Valley, the multiple negative impacts eliminated this alternative.

5.5 Low Flow Conveyance Channel Diversions

The LFCC was designed to increase conveyance and compact deliveries to Elephant Butte Reservoir by minimizing losses from evaporation, transpiration and infiltration. Reclamation does not presently use the LFCC because of the lack of a viable outfall into Elephant Butte Reservoir. Although diversions at San Acacia have been suspended, flows do occur in the LFCC through irrigation return and groundwater seepage. Flows from groundwater influx and drainage increase in the downstream direction. The proposed alternatives offer a suite of operations that range from having no diversions from the Rio Grande to the LFCC to diverting as much a 2,000 cfs from the River while maintaining minimum bypass target at San Acacia.

5.5.1 LFCC – No diversions

The Water Operations Team reviewed the impacts of disallowing all LFCC diversions. The no diversion option would limit Reclamation's operational flexibility to use the LFCC as an alternate conveyance for delivering water to Elephant Butte Reservoir. Though Reclamation does not currently use the LFCC, it could be operated to deliver between 0 and 2,000 cfs if a viable outfall were to be reconstructed at some future date, providing additional operational flexibility to the system. The "No Action Alternative" was modeled to reflect the present condition of no LFCC diversion, although the resumption of diversion to the LFCC is not inconsistent with the "No Action Alternative". Technical teams were cautioned to consider not only the modeled outcome in this respect, but also the potential for LFCC diversion under the "No Action Alternative". However, all quantitative analyses based on model output reflect the no diversion condition.

5.5.2 LFCC – 0 to 2,000 cfs diversions

The Water Operations Team reviewed the impacts of Reclamation retaining the potential operational flexibility to divert from 0 to 2,000 cfs into the LFCC at the San Acacia Diversion Dam. The LFCC could be operated to deliver between 0 and 2,000 cfs if a viable outfall were to be reconstructed at some future date, providing additional operational flexibility to the system. This option was retained for additional analysis because it provides the potential for added operational flexibility if a viable outfall is reconstructed in the future. Several diversion limits within this range were explored among the alternatives.

5.5.3 LFCC – Coordination and Protocol

The "coordination and protocol" alternative assumes that the Federal entities are required to meet presently unknown flow criteria related to endangered species or other issues. The "coordination and protocol" alternative was retained for additional analysis because it represents the potential establishment of currently unknown flow targets within the Socorro Reach of the Rio Grande.

5.5.4 LFCC – Leave 400 cfs past San Acacia

The Water Operations Team reviewed the impacts of requiring that operation of the LFCC leaves at least 400 cfs passing San Acacia Diversion Dam. The "leave 400 cfs past San Acacia" option was eliminated because it limits potential operational flexibility by essentially setting a minimum flow rate below San Acacia Diversion Dam, which is contrary to the goals of Water Operations Review. It was also noted that natural flows within this stretch of the Rio Grande can drop well below 400 cfs when no diversions are occurring.

5.5.5 LFCC – Leave 150 cfs past San Acacia

The Water Operations Team reviewed the impacts of requiring that operation of the LFCC leaves at least 150 cfs passing the San Acacia Diversion Dam. The "leave 150 cfs past San Acacia" option was eliminated because it limits potential operational flexibility by essentially setting a minimum flow rate below San Acacia Diversion Dam, which is contrary to the goals of Water Operations Review. It was also noted that natural flows within this stretch of the Rio Grande could drop below 150 cfs when no diversions are occurring.

5.5.6 LFCC – Leave 50 cfs past San Acacia

The Water Operations Team reviewed the impacts of requiring that operation of the LFCC leaves at least 50 cfs passing the San Acacia Diversion Dam. The "leave 50 cfs past San Acacia" option was eliminated because it limits potential operational flexibility by essentially setting a minimum flow rate below San Acacia Diversion Dam, which is contrary to the goals of Water Operations Review. It was also noted that a flow of 50 cfs below San Acacia provides little or no support to any of the goals of Water Operations Review as outlined in the Purpose and Needs Statement.

5.5.7 LFCC – Leave 50 cfs past San Marcial

The Water Operations Team reviewed the impacts of requiring that operation of the LFCC be limited such that at least 50 cfs arrives downstream and passes the San Marcial gage. The "leave 50 cfs past San Marcial" option was eliminated because it limits potential operational flexibility by essentially setting a minimum flow rate at the San Marcial gage, which is contrary to the goals of Water Operations Review.

5.6 General Description of No-Action Alternative

The No Action Alternative is the water operations alternative that depicts current storage and water delivery operations of federal facilities. The authorized function and current operation of each facility in the No Action is shown in Attachment B. Additional facility and operation descriptions are shown in Section 3.0. The No Action Alternative does include the City of Albuquerque Drinking Water Project, assumed to be operating by year 4 of the 40-year planning period.

6.0 DEVELOPMENT OF COMBINED ACTIONS INTO ALTERNATIVES

The ID and Water Operations Teams identified twenty-one draft alternative operation plans that combine actions from the preliminary screening. These twenty-one alternative plans were based on seven combinations of actions that appeared feasible considering the breadth of events that might occur within a 40-year planning period. Each of the seven combinations differentiated with variations deemed most feasible under dry (1), average (2) and wet (3) conditions. Despite that each plan will be evaluated under a range of dry, average and wet conditions in the 40-year analysis, it was considered worthwhile to build plans on combinations tailored to different water supply conditions in order to allow a more complete analysis of potential options.

Following the Water Operations Team's presentation of the original draft alternatives to the ID NEPA Team, alternatives C3 and E3 were combined due to the similarities in the proposed actions and to limit the number of alternatives. Three additional alternatives designated I1, I2, and I3 were also created at the request of the ID NEPA Team. Alternatives I1, I2, and I3 broaden the spectrum of the alternatives undergoing detailed analysis by including additional variation of LFCC operations. **Table I-6.1** shows the alternatives considered. In this table, Alternatives A-1 to I-1, A-2 to I-2, an A-3 to I-3 represent operational plans considered feasible under, and better suited for, dry, average and wet conditions, respectively. Alternative G represents the present operational condition and is identified as the No-Action Alternative. However, this alternative also implements improved Elephant Butte/Caballo Reservoir coordination and improved communication within the Basin. See Attachment A for more details. Alternative G does not include specific variations addressing dry, average and wet conditions.

Table I-6.1 Draft Operational Alternatives for the Upper Rio Grande Basin Water Operations Review

Alternative	1	2	3
A	Heron waivers – April 30 Abiquiu storage 0 - 20,000 ac-ft Abiquiu channel capacity – 1,200 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept. 30 Abiquiu storage – 0 – 75,000 ac-ft Abiquiu channel capacity – 1,200 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept. 30 Abiquiu storage – 0 – 180,000 ac-ft Abiquiu channel capacity – 1,200 cfs Cochiti channel capacity – 8500 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications
B	Heron waivers – April 30 Abiquiu storage – 0 - 20,000 ac-ft Abiquiu channel capacity – 1,500 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept 30 Abiquiu storage – 0 – 75,000 ac-ft Abiquiu channel capacity – 1,500 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept 30 Abiquiu storage – 0 – 180,000 ac-ft Abiquiu channel capacity – 1,500 cfs Cochiti channel capacity – 8500 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications
C	Heron waivers – April 30 Abiquiu storage – 0 - 20,000 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept 30 Abiquiu storage – 0 – 75,000 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 10,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept 30 Abiquiu storage – 0 – 180,000 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 10,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications
D	Heron waivers – April 30 Abiquiu storage – 0 - 20,000 ac-ft Abiquiu channel capacity – 2,000 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept 30 Abiquiu storage – 0 – 75,000 ac-ft Abiquiu channel capacity – 2,000 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept 30 Abiquiu storage – 0 – 180,000 ac-ft Abiquiu channel capacity – 2,000 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications

Table I-6.1 Draft Operational Alternatives for the Upper Rio Grande Basin Water Operations Review

Alternative	1	2	3
E	Heron waivers – April 30 Abiquiu storage – 0 - 20,000 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 10,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – April 30 Abiquiu storage – 0 – 75,000 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 10,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – April 30 (Sept 30) Abiquiu storage – 0 – 180,000 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 10,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications
F	Heron waivers – April 30 Abiquiu storage – 0 - ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 10,000 cfs LFC – 0 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – April 30 Abiquiu storage – 0 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 10,000 cfs LFC – 0 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – April 30 Abiquiu storage – 0 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 10,000 cfs LFC– 0 cfs Elephant Butte and Caballo protocol/coordination Improved communications
G (Base Run)	No Action – No change in operation Heron waivers – April 30 Abiquiu storage – 0 - ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 7,000 cfs LFC[1] – 0 cfs Elephant Butte and Caballo protocol/coordination Improved communications	No Action – No change in operation Heron waivers – April 30 Abiquiu storage – 0 - ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 7,000 cfs LFC[1] – 0 cfs Elephant Butte and Caballo protocol/coordination Improved communications	No Action – No change in operation Heron waivers – April 30 Abiquiu storage – 0 - ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 7,000 cfs LFC[1] – 0 cfs Elephant Butte and Caballo protocol/coordination Improved communications
I	Heron waivers – April 30 Abiquiu storage – 0 - 20,000 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 500 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept 30 Abiquiu storage – 0 – 75,000 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 1,000 cfs Elephant Butte and Caballo protocol/coordination Improved communications	Heron waivers – Sept 30 Abiquiu storage – 0 – 180,000 ac-ft Abiquiu channel capacity – 1,800 cfs Cochiti channel capacity – 7,000 cfs LFC – 0 – 2000 cfs Elephant Butte and Caballo protocol/coordination Improved communications

1 – The LFCC is modeled with a diversion of 0 cfs in the Base Run because this is the present operational condition given to the current lack of a functional outflow channel into Elephant Butte Reservoir. However, under existing operational rules, diversions of up to 2,000 cfs are permitted in the LFCC.

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7.0 EVALUATION OF ALTERNATIVES

7.1 Methods

The Water Operations Team reviewed historic hydrologic data and considered multiple operational processes and constraints in the analysis of the alternatives. For example, the team considered information such as:

1.0 the number of years there was carryover storage at Abiquiu Reservoir,
2.0 the number of days flow reached channel capacity, and
3.0 historic peak flows in the river.

Preliminary analyses were qualitative based on knowledge integrated from data and operational experience.

More detailed analyses utilized the hydrologic model, URGWOM[10], developed with RiverWare[11] software. The model was used to compare and visualize water operations under selected alternative plans over the 40-year planning period. For this analysis, a 40-year synthetic sequence of flows were derived that represented the long-term climate condition, including drought, wet and average periods. Because the period of record available to URGWOM generally spanned a wet period, the available data were not used directly to generate the 40-year sequence of hydrology. Rather, the available data were used to develop a representative sequence that would capture a greater number of dry years in order to be representative of long-term conditions. This method and the resulting hydrology used to drive the 40-year URGWOM model for this planning analysis are described in an Appendix to this report.

The model results were used to compare the relative magnitude or occurrence of flood control problems, Rio Grande Compact delivery, conservation storage, carryover storage, reservoir drawdown, peak flow, sediment transport, water supply delivery, overbank flooding and other hydrologic impacts.

7.2 Initial Rating of Alternatives

Using the methods described above, and applying the judgment and experience of the water operations team, the 21 alternatives were rated using a numerical scale for multiple criteria. The criteria, their relative weighting, and the scores assigned are shown on **Table I-7.1**. From this analysis, alternatives B-3, C-3, D-3, E-3 and I-3 were most highly rated, with C-3 receiving the highest numerical score.

For consideration as final alternatives for detailed evaluation, the team recommended to the ID Team several alternatives that appeared to provide a high level of flexibility for the resources at each facility, recognizing that flexibility in operations is critically important to the ability to balance variable water supply conditions and demands. The ID Team chose to retain several of the alternatives among those rated highly by the Water Operations Team. In addition, the ID Team chose to retain alternatives I-1 and I-2 with more restrictive operational flexibility. For cases I-1 and I-2, the Low Flow Conveyance Channel is restricted to maximum diversions of 500, and 1,000 cfs (less than the value of 2,000 cfs that represents maximum flexibility). These were included to broaden the spectrum of alternatives analyzed in detail.

Alternatives B-3, D-3, E-3(C-3), I-1, I-2 and I-3, along with the No-Action Alternative, G, were retained for detailed screening. Alternative C-3 was considered similar enough to E-3 that it could be included as a variant of the alternative E-3.

7.3 Discussion of Alternatives not Carried Forward for Detailed Analysis

Alternative A1, A2 and A3 were considered but discarded. The proposed alternatives were to store conservation water at Abiquiu Reservoir in the amounts of 20,000, 75,000 and 180,000 acre-feet in A1, A2 and A3, respectively. Other actions that were considered in the alternatives were a change in the Heron waiver day and the Cochiti channel capacity. Two actions that did not change in the three variants of alternatives was the channel capacity (1,200 cfs) at Abiquiu and the LFCC diversions (2,000 cfs maximum). Alternatives A1, A2, A3 were eliminated because they were associated with several negative impacts:

m) a decrease in operation flexibility;

n) greater difficulty meeting Rio Grande Compact delivery requirements;

o) an increased number of years with carryover storage;

p) difficulty in satisfying downstream demands;

q) and, operation of the Rio Chama at channel capacity throughout the snowmelt runoff and irrigation season in a large number of years

The Corps operates its projects to evacuate flood storage as rapidly as conditions downstream permit. A 1,200 cfs channel capacity below the dam would limit the Corps ability to evacuate flood storage and therefore create carryover storage in the reservoir on a regular basis over the 40 year hydrologic sequence. A key difficulty is presented with the ability to meet demands downstream; inspection of historic data indicates that a 1,200 cfs release from Abiquiu Dam is insufficient to meet demands downstream, considering that endangered species releases below Abiquiu Dam have been as high as 600 cfs, and irrigation releases in the past have been between 1,000 – 1,200 cfs.

Alternative B1, B2 were considered but discarded. The proposed alternatives were to store conservation water at Abiquiu Reservoir in amounts up to 20,000, 75,000 and 180,000 acre-feet in B1, B2 and B3, respectively. Other actions that were included were a change in the Heron waiver date and the Cochiti channel capacity. Two actions that did not change in the three variants of the alternatives were the channel capacity (1,500 cfs) at Abiquiu and the LFCC diversions (2,000 cfs maximum). These alternatives increased operational flexibility and were viable options, but the ability to store conservation water up 180,000 acre-feet was the alternative that was chosen from this group. The Water Operations decided that alternative B3 provided the maximum flexibility when operating the system. Alternatives B1 and B2 showed no readily identifiable benefits associated with the lower limit on conservation storage. Decreasing the channel capacity below Abiquiu dam does decrease the level of protection that the project can provide. In the last few years a 1,500 cfs release from Abiquiu Dam would be enough to meet demands downstream.

Alternative C1, C2, C3 were considered but discarded. The proposed alternatives were to store conservation water at Abiquiu Reservoir in the amounts of 20,000, 75,000 and 180,000 acre-feet in C1, C2 and C3, respectively. Other actions that were considered in the alternatives were a change in the Heron waiver day and the Cochiti channel capacity. Two actions that did not change in the three variants of the alternatives were the channel capacity (1,800 cfs) at Abiquiu and the LFCC diversions (2,000 cfs max). These alternatives increased operational flexibility and were viable options. The C alternatives are identical to the E alternatives with the exception of the Heron waiver date. Alternative C3 provides the greatest flexibility, but due to its similarity to Alternative E3, is not carried forward for separate analysis.

Alternative C1 and C2 are not carried forward, as there is no clear benefit to restricting the ability for conservation storage. Alternative C3 will be merged into a variation Alternative E3 in detailed analysis.

Alternatives D1 and D2 were considered but discarded. The proposed alternatives were to store conservation water at Abiquiu Reservoir in the amounts of 20,000, 75,000 and 180,000 acre-feet in D1, D2 and D3, respectively. Other actions that were considered in the alternatives were a change in the Heron waiver day and the Cochiti channel capacity. Alternatives D2 and D3, the Cochiti channel capacity is increased to 10,000 cfs and the Heron waiver limit is shifted to September 30. The two actions that did not change in the three variations of the D alternatives were the channel capacity (2000 cfs) at Abiquiu and the LFCC diversions (2,000 cfs max). These alternatives increased operational flexibility and were viable options. But the ability to store conservation water up 180,000 acre-feet was the alternative that was chosen from this group. The Water Operations Team decided that alternative D3 provided the maximum flexibility when operating the system. Alternative D1 and D2 are not carried forward, as they offer little benefit over D3, which is carried forward. An added benefit is that increasing the channel capacity below Abiquiu dam does raise the level of protection that the project can provide and increases compact deliveries.

Alternatives E1, E2 were considered but discarded. The proposed alternatives were to store conservation water at Abiquiu Reservoir in the amounts of 20,000, 75,000 and 180,000 acre-feet for E1, E2 and E3, respectively. Four actions that did not change in the three variants of the alternatives are the channel capacity (1,800 cfs) at Abiquiu, channel capacity at Cochiti (10,000 cfs) and the LFCC diversions (2,000 cfs max), and no change in the Heron waiver date. These alternatives increased operational flexibility and were viable options. However, the ability to store conservation water up 180,000 acre-feet was the alternative that was chosen from this group. The Water Operations team decided that alternative E3 provided the maximum flexibility when operating the system. Alternatives E1 and E2 are not carried forward, as they offer little benefit over E3. Alternative E3 is carried forward for further analysis and will be analyzed with the change in Heron waiver (to September 30, from plan C3) as a minor variant. Increasing the channel capacity below Cochiti dam increases the level of protection that the project can provide, increases sediment transport, provides for overbank flooding and increases compact deliveries.

Alternatives F1, F2, F3 are all the same in the table. Alternative F was considered but discarded. The proposed alternatives had no conservation water storage at Abiquiu Reservoir, a channel capacity (1,800 cfs) at Abiquiu, a channel capacity at Cochiti (10,000 cfs), no LFCC diversions, and no change in the Heron waiver date. This alternative was eliminated because it decreased operational flexibility. The inability to store water upstream was one of the reasons this alternative was eliminated. Another reason this alternative was eliminated is that alternative E3 uses the same channel capacity below Cochiti Dam. Furthermore, this alternative bears enough similarity to the No Action Alternative (as modeled for the present physical condition of the LFCC) that separate and detailed consideration was deemed unnecessary.

Alternatives I1, I2, I3 were considered and not discarded. This suite of alternatives is discussed in the next section.

7.4 Discussion of Alternatives Carried Forward for Detailed Analysis

The proposed alternative B-3 focuses on storing conservation water at Abiquiu Reservoir up to 180,000 acre-feet. Other actions that were included in the alternative are a change in the Heron waiver date, Cochiti channel capacity, Abiquiu channel capacity, and LFCC diversions (2,000 cfs max.). Alternative B-3 provided some operational flexibility. The benefits associated with this alternative are the ability to store conservation water, Heron waiver date, operation of the low flow, and increased channel capacity below Cochiti Lake. The disadvantage of this alternative is the decrease in channel capacity below Abiquiu Dam. Decrease in channel capacity results in a decrease in the level of protection that the project provides for flood control. This also affects New Mexico's ability to deliver water to Elephant Butte Reservoir for compact obligations.

The proposed alternative D-3 allows storage of conservation water at Abiquiu Reservoir up to 180,000 acre-feet. Other actions that were included in the alternative are a change in the Heron waiver date, Abiquiu channel capacity, and the LFCC diversions (2,000 cfs max.). Alternative D-3 provided some operational flexibility. The benefits associated with this alternative are the ability to store conservation water, the Heron waiver date, and operation of the LFCC, ability to meet compact deliveries, and increased channel capacity below Abiquiu Dam. The disadvantages of this alternative is that the increase in channel capacity below Abiquiu would damage diversion structures, head gates, cause bank erosion and increased overbank flooding. The increase in channel capacity at Abiquiu would decrease the level of flood protection at Cochiti, since the channel capacity below the dam remains at 7,000 cfs.

The proposed alternative E-3 allows for storage of conservation water at Abiquiu Reservoir up to 180,000 acre-feet. Other actions in this alternative include a change in channel capacity at Cochiti of 10,000 cfs and LFCC diversions to the limit of 2,000 cfs. To limit the number of alternatives analyzed in detail, action alternatives C-3 and E-3 were combined due to similarities in proposed actions. The benefits associated with this alternative are the increased channel capacity below Cochiti Dam, increased level of flood protection, increased sediment transport, increased overbank flow, increased compact deliveries, the ability to store conservation water and utilizing the LFCC. The disadvantages of this alternative are that the Heron waiver date is April 30, and an increase of channel capacity below Cochiti Dam which would require increased maintenance to accommodate higher flows. Changing the waiver date at Heron to September would provide the maximum flexibility.

The proposed alternatives in I-1, I-2, I-3, allow for storage of conservation water at Abiquiu Reservoir up to limits of 20,000, 75,000 and 180,000 acre-feet for I1, I2 and I3, respectively. The LFCC is operated to maximum diversion limits of 500, 1,000, and 2,000 cfs, respectively, under the three variations. All 'I' alternatives included a channel capacity of 1,800 cfs at Abiquiu, channel capacity of 7,000 cfs at Cochiti and no change in the Heron waivers usage date. With the exception of the LFCC limitations, these alternatives increase operational flexibility and are viable. Although the ability to make compact deliveries is lessened with restricted diversions at the LFCC, these plans are maintained for further analysis due to interest from the ID Team in expanding the breadth of alternatives evaluated. The disadvantages of this suite of alternatives is that the Heron waiver date does not change (April 30), Cochiti channel capacity remains the same, operation of the LFCC is decreased in I-1 and I-2, and there is a decreased ability to store conservation water in I-1 and I-2.

The No-Action Alternatives G1, G2, and G3 provide some operational flexibility but deviations are needed from the normal operations in order to accommodate the flexibility. The benefits associated with this alternative are the ability to extend Heron Reservoir waiver date (April), maintains channel capacity below Abiquiu Reservoir, maintains the ability to fulfill compact delivery obligations, and releases from Abiquiu do not impact water users needs downstream of the dam. The disadvantages of this suite of alternatives are that you need a deviation to store native water in Abiquiu Reservoir at the present time, channel capacity for Cochiti Dam is 7,000 cfs, Heron Waiver date is fixed, and the LFCC is not operational.

7.5 Results of Detailed Alternatives Screening

To illustrate some of the differences among the alternatives, hydrologic modeling was conducted using URGWOM at a daily timestep for the 40-year evaluation period. The model runs were structured to represent the maximum where ranges were represented in an alternative. For example, if an alternative indicated that conservation storage could occur up to 75,000 acre-feet, then, the rules were set such that storage in this amount would occur, if possible. Similarly, if the range of diversion identified for the LFCC was 0 – 2,000 cfs, then, the diversion was set at 2,000 cfs, if possible. While these simplifications were necessary to render the modeling practical, it must be understood that operators may have discretion to operate within the range, and not always at the extreme value of the range. The model results, therefore, represent what could result under the alternative – these results are useful for comparative purposes. However, it is important to consider the flexibility within each alternative qualitatively where specific model runs representing other possible manifestations of the alternative are not provided.

The model results are most useful for making comparisons between alternatives, but, due to limitations in assumptions and development within URGWOM, in some cases, may not be representative of absolute conditions. Particularly under lower flow conditions and in the reach below San Acacia, the model may not accurately represent flows. Therefore, projections of Compact deliveries or numbers of days of flow below a particular low value, i.e., below 200 cfs at San Acacia, may only be meaningful in a comparative sense.

Figures in Attachment D show some of the comparisons among alternatives. **Figure I-D.1** shows a 40-model year flow sequence at Otowi gage at Cochiti Dam. **Figure I-D.2** and **Figure I-D.3** evaluate the effects of different Abiquiu channel capacities and the effect they have on storage in Abiquiu Reservoir along with number of days per year channel capacity would be reached. **Figure I-D.8** compares the peak flows at Albuquerque for each alternative. **Figure I-D.9** compares the accumulated NM credit storage using various volumes of release and assumes a storage of 75,000 acre-feet in the conservation pool at Abiquiu Reservoir. **Figure I-D.10** and **Figure I-D.11** compare average annual storage in Abiquiu and Cochiti for all alternatives for 40 model years. **Figure I-D.12** through **Figure I-D.16** compare average annual flow at Albuquerque, Chamita, El Vado, Otowi, and San Acacia for all alternatives for 40 model years. Model years termed MY2003 to MY2042 are analogous to years 1 through 4 of the synthetic year flow sequence and are not intended to reflect condition for any specific future calendar year. Rather, they reflect a sequence of varied conditions that allow hypothetical future conditions under different alternatives to be compared.

Tables in Attachment E provide a summary of statistical data for the different action alternatives. **Tables I-E.1 through I-E.4** summarize pool elevation data for Abiquiu, Cochiti, El Vado and Heron. **Tables I.E-5 and 6** summarize pool storage for Abiquiu and Cochiti. **Tables I.E-7 through I-E.11** summarize flow in Albuquerque, Chamita, El Vado, Otowi and San Acacia.

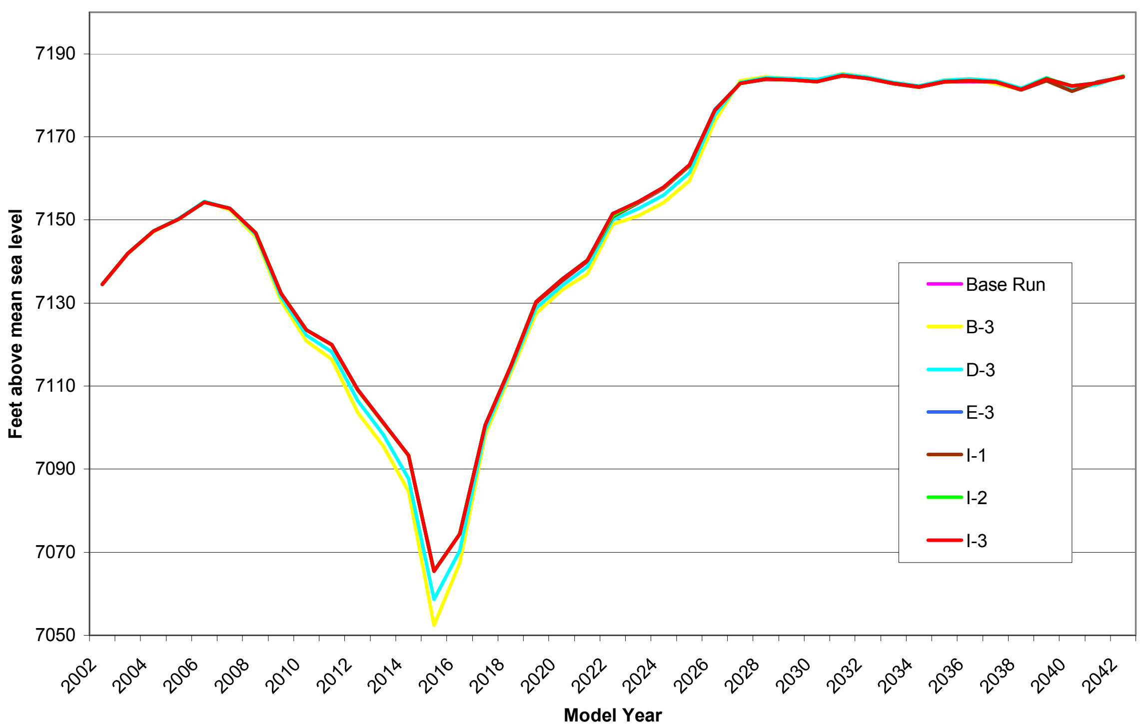
The Water Operations Team rated the subset of final alternatives using comparative model results in combination with engineering judgment and an understanding of system operations. The alternatives were rated relative to one another using a set of weighted criteria. The results of this analysis are provided on **Table I-7.2**. In consideration of the difficulty of anticipating all possible water supply conditions and future demands, the Water Operations Team recommends that flexibility in operations be considered a parameter of high value. This perspective is reflected in the weighting and scoring on **Table I-7.2**. From this analysis, the Water Operations Team prefers alternative E.

7.6 Impacts of Action Alternatives on Reservoirs

7.6.1 Heron Reservoir

Reservoir elevation was used to gauge the impact of each of the six action alternatives on Heron Reservoir. Reservoir elevation as simulated within URGWOM for each of the six alternatives was plotted and compared to the simulated base run elevation for the 40 year planning period. From May of Model Year (MY) 2006 to November of MY 2026, reservoir elevation as modeled by action alternatives B-3 and D-3 show significant departures below the base run elevation. From November of MY 2026 to the end of the 40 year planning period, reservoir elevations for alternatives B-3 and D-3 track slightly above the base run. During this later period, the average annual reservoir elevation as modeled using action alternatives B-3 and D-3 tracks less than 1 ft above the base run, although average weekly elevations exceed 2 ft above the base run during several years. Action alternatives E-3, I-1, I-2, and I-3 track well with the base run showing insignificant departures from the base run elevation throughout the 40 year planning period.

Heron Average Annual Pool Elevation (Model Year 1-40)

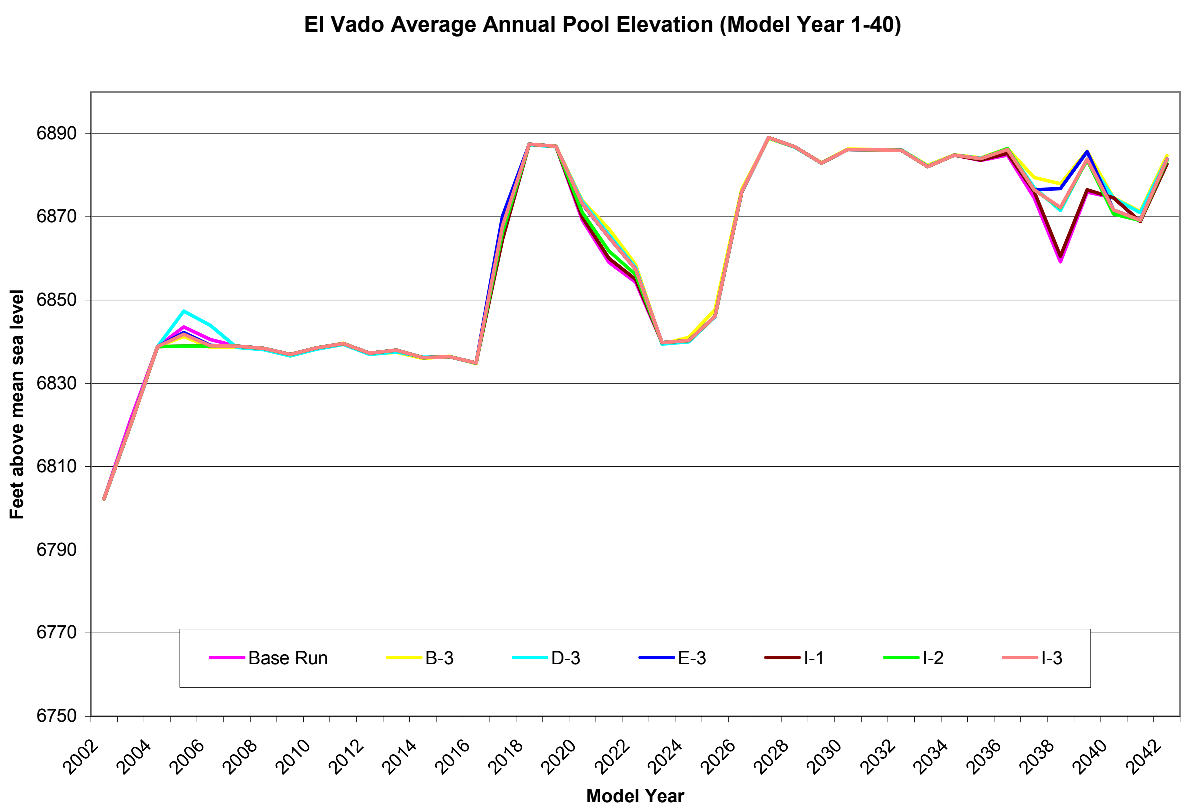


The differences observed in Heron reservoir elevation as modeled with action alternatives B-3 and D-3 appear to be the result of these alternatives having modeled SJC waiver dates of September 30 and August 31, respectively. The model is set up to assume that any excess SJC water within Heron that does not have a downstream destination will either revert back to the federal pool in Heron, or be transferred to MRGCD for use in Middle Valley irrigation during that same year if MRGCD is experiencing a shortage in supply. With the extended waiver dates modeled in B-3 and D-3, a greater volume of this SJC contractor water is being transferred to MRGCD during the extended dry period during the first portion of the 40 year planning period. Since any water that is not transferred or delivered prior to the waiver date reverts back to the Federal pool, these additional transfers to MRGCD result in less water reverting to the Federal pool during this dry period.

Although the total volume of additional water that is transferred to MRGCD because of the extended waiver dates modeled in B-3 and D-3 is only on the order of 6,000 to 7,000 acre-ft over the entire period, a significant drop in reservoir elevation occurs because of the critically low storage that is modeled within Heron during this time. At extremely low reservoir elevations, such as are modeled to occur in MY 2015 and 2016, a difference in storage of 6,000 acre-ft results in an approximate 12 ft reduction in reservoir elevation at Heron. Similarly, a 6,000 acre-ft reduction in reservoir content explains the 2 ft to 4 ft departures below the base run elevation observed during MY 2017 through MY 2027.

7.6.2 El Vado Reservoir

As in Heron Reservoir, reservoir elevation was used to gauge the impact of each of the six action alternatives on El Vado Reservoir. Reservoir elevation was used to gauge the impact of each of the six action alternatives El Vado Reservoir. Reservoir elevation as simulated within URGWOM for each of the six alternatives was plotted and compared to the simulated base run elevation for the 40 year planning period. In general, reservoir elevation from all action alternatives tracked fairly closely to the base run with a few notable exceptions. Relatively large departures from the base run elevation (greater than 5 ft above base run) can be observed from April of MY 2020 to September of MY 2022, and even larger departures (greater than 30 ft above base run) are observed from August of MY 2037 through June of MY 2039. These two periods were examined in greater detail to attempt to determine the cause of these relatively large deviations from the base run reservoir elevations.



The primary component of the action alternatives impacting El Vado reservoir elevation and storage as modeled over the 40 year period appears to be associated with the modeled operation of the Low Flow Conveyance Channel (LFCC) and modeled increases in channel capacity below Abiquiu and Cochiti Reservoirs. This conclusion is based on a review of Elephant Butte and Caballo Reservoir contents as an indicator of Rio Grande Compact usable water and native Rio Grande storage in El Vado as an indicator of whether or not New Mexico is under Article VII storage restrictions.

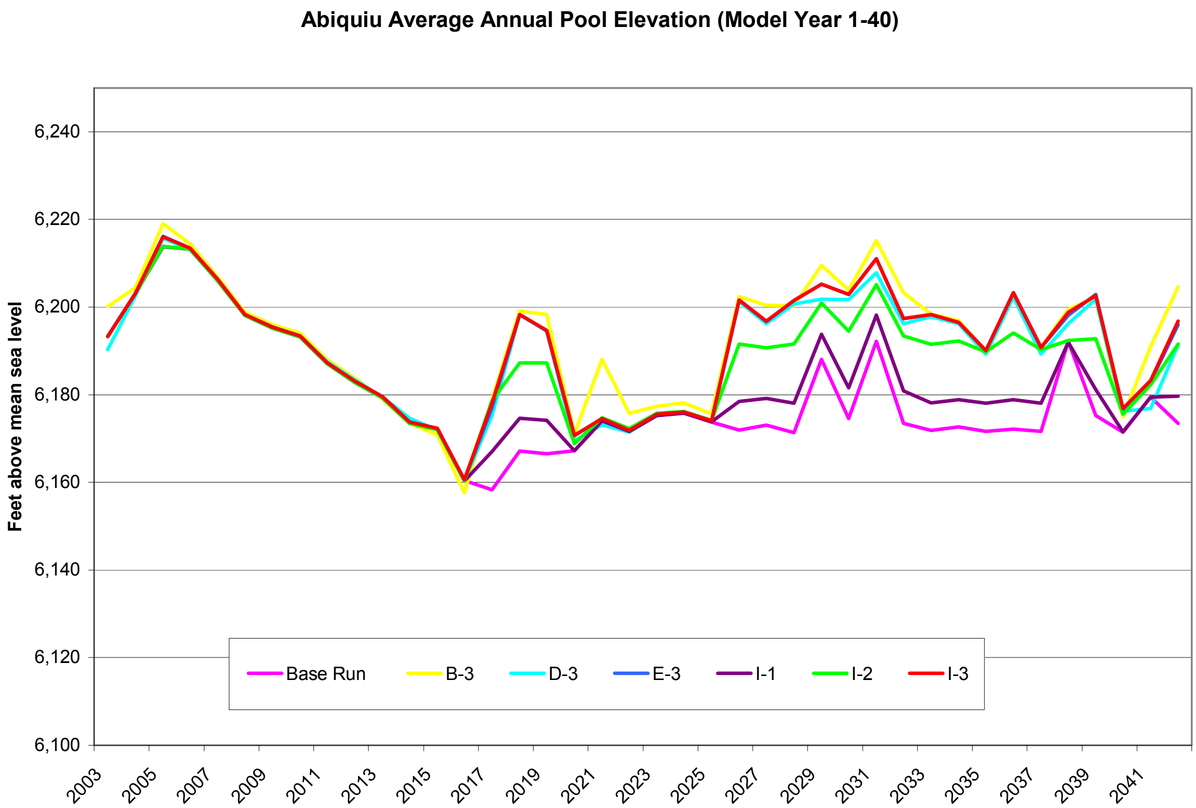
During extended periods within the 40 year planning horizon when Rio Grande Compact usable water either remains above or below the 400,000 acre-ft threshold, all six action alternatives track well together with rather insignificant departures from the base run elevation. It is believed that this is because all alternatives as well as the base run are initiating storage in El Vado in a similar fashion starting at near the same point each spring. However, during those periods when Article VII storage restrictions are repeatedly lifted and then enacted as Rio Grande Compact usable water oscillates around 400,000 acre-ft, noticeable departures from the base run elevation are observed. It appears that those alternatives that have the modeled ability to deliver water to Elephant Butte either more rapidly through higher channel capacity, and/or more efficiently through the LFCC are able to more efficiently capture the runoff in El Vado resulting in greater reservoir storage and greater water surface elevation.

During the MY 2037 to MY 2039 period, I-1 has the least departure from base run compared to the other alternatives which might be expected considering I-1 is the closest to the modeled base run conditions. Action Alternatives D-3, I-2, and I-3 are then clustered together with somewhat greater departures from the base run, perhaps due to LFCC operations being modeled to deliver up to 1,000 to 2,000 cfs. Action alternatives B-3 and E-3 are then grouped together with even greater departures, which may be a result of these alternatives being modeled with LFCC flows up to 2,000 cfs and below Cochiti channel capacity set to 8,500 to 10,000 cfs.

The modeled waiver delivery date for annual SJC water allocations out of Heron appears to have a lesser impact on modeled El Vado storage and reservoir elevation. During hydrologicaly and meteorologically wet periods when El Vado remains relatively full, the ability to hold MRGCD's annual SJC water allocation later in Heron Reservoir seems to result in El Vado being "topped off" later in the year after storage space is available following releases of stored water for Middle Valley irrigation. This results in slightly higher average reservoir elevations in El Vado for action alternativesB-3 and D-3, and a slightly smaller portion of MRGCD's annual allocation reverting to the Federal SJC pool in Heron after the modeled waiver date is reached on August 31 or September 30. All other alternatives as well as the base run were modeled with a Heron waiver date of April 30. These conclusions are based on the observed modeled storage within MRGCD's Heron SJC account and the modeled total storage in El Vado Reservoir for action alternatives B-3 and I-3.

7.6.3 Abiquiu Reservoir

Reservoir elevation was used to gauge the impact of each of the six action alternatives on Abiquiu Reservoir. The elevation as simulated within URGWOM for each of the six alternatives was plotted and compared to the simulated base run elevation for the 40-year planning period. In general, reservoir elevation from all action alternatives tracked close to the base run for the first 15 years. Departures from the base run elevation occur when conservation water is being stored. The range in departures (between 5 to 32 ft above the base run) depends on the volume of the conservation water being stored in each alternative and the channel capacity below Abiquiu Reservoir.



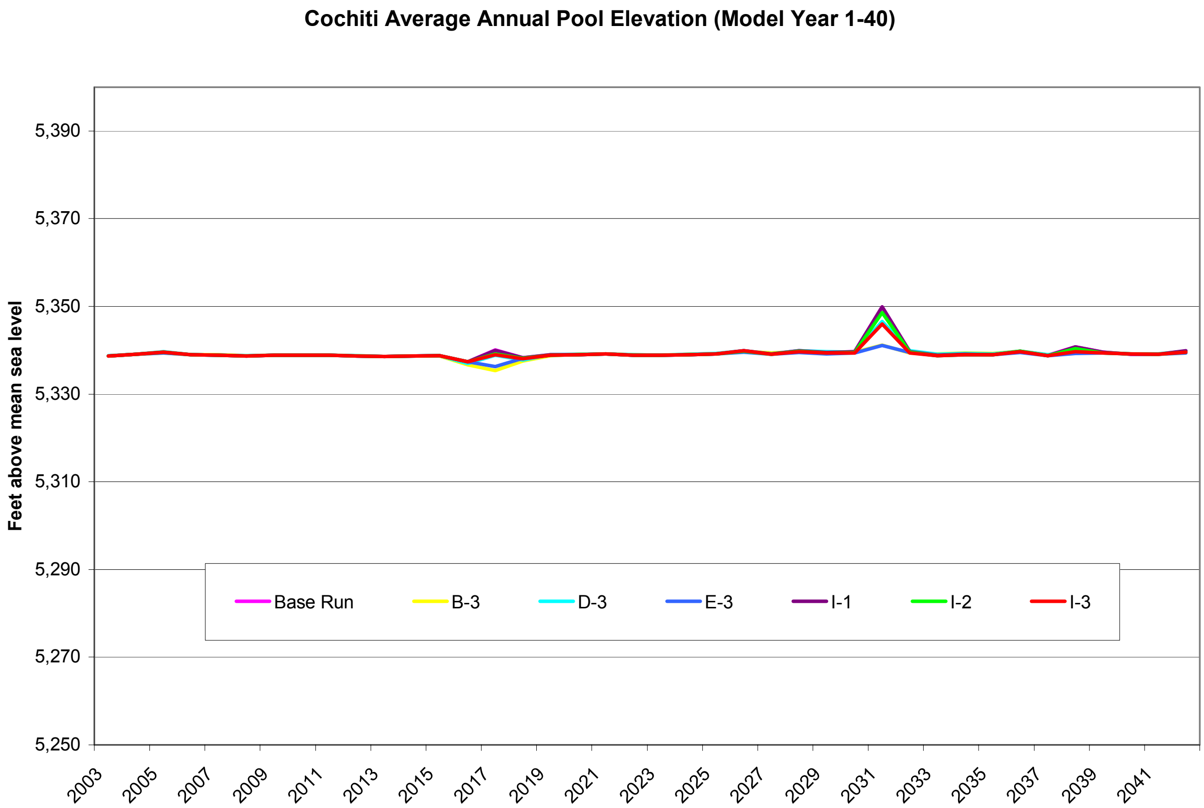
The primary components of the action alternatives influencing Abiquiu Reservoir elevation and storage as modeled over the 40-year is associated with the modeled operation of the LFCC, conservation storage space available by alternative, and channel capacity below Abiquiu and Cochiti Reservoirs. Conservation storage can only take place when New Mexico is not in Article VII of Rio Grande Compact. Review of Elephant Butte and Caballo Reservoir contents as an indicator of Rio Grande Compact usable water shows that storage at Abiquiu Reservoir under each of the action alternatives occurs within 0 to 8 days of each other.

During extended periods within the 40-year planning horizon when Rio Grande Compact usable water remains above the 400,000 acre-feet threshold, all six-action alternatives have departures from the base run elevation. This is because all alternatives are initiating conservation storage in Abiquiu Reservoir. The alternatives that have the modeled ability to deliver water to Elephant Butte either more rapidly through higher channel capacity, and/or more efficiently through the LFCC are able to start the capture of conservation water earlier in Abiquiu Reservoir.

Alternative I-1 and I-2 have the least departure from base run compared to the other alternatives which is expected since I-1 and I-2 are the closest to the modeled base run condition. Action Alternatives B-3, D-3, E-3, and I-3 are then clustered together with greater departures from base run, due to the amount of conservation storage space available under each alternative. There is no impact on the ability to storage San Juan-Chama water in any of the alternatives.

7.6.4 Cochiti Reservoir

Reservoir elevation was used to gauge the impact of each of the six action alternatives (B-3, D-3, E-3, I-1, I-2, I-3) selected by the Water Operations Review Interdisciplinary Team on Cochiti Reservoir. The elevation as simulated within URGWOM for each of the six alternatives was plotted and compared to the simulated base run elevation for the 40-year planning period. The reservoir elevation from all action alternatives tracked close to the base run for the 40-year period. The range in departures (between 0 to 9 ft below the base run) depends on the volume of conservation water being stored upstream, and the channel capacity below Abiquiu Reservoir and Cochiti Lake.



The main component of the action alternatives influencing Cochiti Lake elevation and storage over the 40-years is associated with the modeled channel capacity below and Cochiti Lake. A change in channel capacity below Abiquiu Reservoir in the action alternatives influences Cochiti Lake inflow by -300 or +200 cfs. A change in channel capacity below Cochiti has a larger impact. The Base Run channel capacity below Cochiti is 7,000, while some of the action alternatives have a channel capacity of 8,500 and 10,000 cfs. Cochiti Lake is operated to pass inflow up the channel capacity so the higher the release the less chance to store water.

In year 2017, the elevations in B-3 and E-3 are lower because of the stepped release function. Alternative B-3 and E-3 models over release water in storage in an effort to get down to the permanent pool. Year 2031 shows the largest departure from the base run condition. The large channel capacity in alternatives B-3 and E-3 allow Cochiti to be operated with very little storage above the Base Run condition.

Table I-7.1 Decision Support

DECISION SUPPORT: Alternative Performance vs. Water Operations Performance Measures

	Performance Measure	Compatibile w/Flood Control Operations	Compatibile w/Rio Grande Compact	Improves System Operational Flexibility	Supports Water Delivery	Maximizes Conservation Storage Opportunities	Maximizes Peak Discharge Opportunitie s	Maximizes Sediment Transport Opportunities	Supports Desirable Winter Flows	Supports Recreational Uses	Supports Stable Reservoir Levels		
	Threshold Criterion	X	X		X								
	ALTERNATIVE / Weight	0.20	0.20	0.15	0.15	0.10	0.08	0.05	0.04	0.02	0.01	Weighted Average Percent Met	Rank
1	**Plan G - No Action (Baseline)**	**7**	**4**	**5**	**8**	**0**	**6**	**6**	**5**	**5**	**5**	**52.80%**	**19**
2	Plan A1- Dry Hydrology Criteria	4	5	3	2	3	2	2	3	3	3	33.20%	22
3	Plan A2 - Normal Hydrology Criteria	4	5	4	2	7	2	2	1	1	1	37.30%	21
4	Plan A3 - Wet Hydrology Criteria	4	5	5	2	10	2	2	1	1	1	41.80%	20
5	Plan B1 - Dry Hydrology Criteria	6	7	6	7	3	5	5	4	4	4	57.80%	18
6	Plan B2 - Normal Hydrology Criteria	7	7	8	8	7	7	7	5	5	5	71.60%	16
7*	**Plan B3 - Wet Hydrology Criteria**	**9**	**9**	**10**	**8**	**10**	**8**	**9**	**5**	**5**	**5**	**87.40%**	**6**
8	Plan C1 - Dry Hydrology Criteria	7	8	6	8	3	6	6	5	5	5	65.30%	17
9	Plan C2 - Normal Hydrology Criteria	10	10	8	9	7	9	8	6	5	5	87.60%	5
10*	**Plan C3 - Wet Hydrology Criteria**	**10**	**10**	**10**	**10**	**10**	**9**	**9**	**6**	**5**	**5**	**95.60%**	**1**
11	Plan D1 - Dry Hydrology Criteria	10	8	7	10	3	8	8	5	5	5	78.40%	11
12	Plan D2 - Normal Hydrology Criteria	10	8	8	10	7	8	8	5	5	5	83.90%	8
2*	**Plan D3 - Wet Hydrology Criteria**	**10**	**10**	**10**	**10**	**10**	**8**	**8**	**5**	**5**	**5**	**93.90%**	**3**
14	Plan E1 - Dry Hydrology Criteria	10	10	6	8	3	9	9	5	6	5	79.40%	10
15	Plan E2 - Normal Hydrology Criteria	10	10	7	9	7	9	9	6	6	5	86.80%	7
16*	**Plan E3 - Wet Hydrology Criteria**	**10**	**10**	**9**	**10**	**10**	**9**	**9**	**6**	**6**	**5**	**94.30%**	**2**
17	Plan F1 - Dry Hydrology Criteria	10	8	5	10	0	9	9	6	6	6	74.40%	13
18	Plan F2 - Normal Hydrology Criteria	10	8	5	10	0	9	9	6	6	6	74.40%	13
19	Plan F3 - Wet Hydrology Criteria	10	8	5	10	0	9	9	6	6	6	74.40%	13
20**	**Plan I1 - Dry Hydrology Criteria**	**10**	**6**	**6**	**10**	**3**	**7**	**7**	**6**	**6**	**6**	**72.30%**	**15**
21**	**Plan I2 - Normal Hydrology Criteria**	**10**	**8**	**8**	**10**	**7**	**7**	**7**	**6**	**6**	**6**	**83.30%**	**9**
22*	**Plan I3 - Wet Hydrology Criteria**	**10**	**10**	**10**	**10**	**10**	**7**	**7**	**6**	**6**	**6**	**93.30%**	**4**

NOTES:

1. Performance Measure weights sum to 100 points total
2. Weighted Average Percent Met multiplies sums (scores * weights) for all measures
3. Alternatives are ranked from highest to lowest score
4. Top four alternatives selected for detailed analysis; supplemented by ID-NEPA Team dry and normal alternative selections

7*	**Alternative Selected by Water Operations Rankings for Detailed Analysis**
20**	**Alternative Selected by ID-NEPA Team for Broader Sepctrum Operations Analysis**
10***	**Alternative combined with E-3 for detailed analysis**

Table I-7.2 Decision Support

DECISION SUPPORT: Alternative Performance vs. Water Operations Performance Measures

	Performance Measure	Compatibile w/Flood Control Operations	Compatibile w/Rio Grande Compact	Improves System Operational Flexibility	Supports Water Delivery	Maximizes Conservation Storage Opportunities	Maximizes Peak Discharge Opportunities	Maximizes Sediment Transport Opportunities	Supports Desirable Winter Flows	Supports Recreational Uses	Supports Stable Reservoir Levels		
	Threshold Criterion	X	X		X								
	Weight	0.20	0.20	0.15	0.15	0.10	0.08	0.05	0.04	0.02	0.01	Weighted Average Percent Met	Rank
	ALTERNATIVE												
1	Plan G - No Action (Baseline)	70	10	0	20	0	30	40	30	20	20	25.00%	7
7	Plan B3 - Wet Hydrology Criteria	90	90	50	70	100	70	90	30	20	20	76.00%	4
2	Plan D3 - Wet Hydrology Criteria	100	90	90	90	100	70	70	30	20	50	86.00%	2
16	Plan E3 - Wet Hydrology Criteria	100	100	95	100	100	90	90	70	70	60	96.00%	1
20	Plan I1 - Dry Hydrology Criteria	100	20	10	30	30	50	50	70	40	60	44.00%	6
21	Plan I2 - Normal Hydrology Criteria	100	70	50	70	70	50	50	70	50	60	70.00%	5
22	Plan I3 - Wet Hydrology Criteria	100	90	85	90	100	50	50	70	70	60	86.00%	3

NOTES:

NOTES:

1. Use quantitative measures wherever possible: acre-feet of water delivered; acres habitat available; days of flooding > 100-year flood; etc.
2. Use criteria weights that sum to 100 points total
3. Apply the following equation to performance criteria in each cell - i.e., performance value* weight = cell number
4. Identify critical thresholds on applicable decision criteria

8.0 ATTACHMENT A OPERATIONAL FLEXIBILITIES AND PRELIMINARY SCREENING

Preliminary Screening of Operational Feasibility by Facility and Action.

This preliminary screening table documents the actions considered at each facility for which some flexibility was identified through internal and public scoping. It summarizes the facility, the action under consideration, the attribute that would be addressed, whether or not the action under consideration would represent a fatal flaw with respect to the attribute and the rationale. In identifying whether or not the action would represent a fatal flaw, the Purpose and Need Statement for Water Operations Review was considered. The following summarizes the elements of the Purpose and Need Statement that were considered in this preliminary screening evaluation.

Need: Under various existing legal authorities, and subject to allocation of supplies and priority of water rights under state law, the COE and BOR operate dams, reservoirs, and other facilities in the upper Rio Grande basin to:

N1. Store and deliver water for agricultural, domestic, municipal, industrial, and environmental uses;

N2. Assist the ISC in meeting downstream water delivery obligations mandated by the Rio Grande Compact;

N3. Provide flood protection and sediment control; and

N4. Comply with existing law, contract obligations, and international treaty.

Purpose: The Upper Rio Grande Basin Water Operations Review will be the basis of, and integral to, preparation of the Water Operations EIS. The purpose of the Review and Water Operations EIS is to:

P1. Identify flexibilities in operation of federal reservoirs and facilities in the upper Rio Grande basin that are within existing authorities of COE, BOR, and NMISC, and in compliance with state and federal law;

P2. Develop a better understanding of how these facilities could be operated more efficiently and effectively as an integrated system;

P3. Formulate a plan for future water operations at these facilities that is within the existing authorities of BOR, COE, and NMISC; complies with state, federal, and other applicable laws and regulations; and assures continued safe dam operations;

P4. Improve processes for making decisions about water operations through better interagency communications and coordination, and facilitation of public review and input; and

P5. Support compliance of the COE, BOR, and NMISC with applicable law and regulations, including but not limited to the National Environmental Policy Act and the Endangered Species Act.

The attributes of interest and rationale for evaluating the action with respect to each attribute are based on engineering judgment and knowledge of the Rio Grande Basin. Those attributes that meet do not appear to be inconsistent with specific purpose and/or need statements are marked with an X in the columns on the right. If an attribute contains a “fatal flaw” that would override other considerations, an X is placed in the column labeled Fatal Flaw.

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
Heron	Waivers – None	Water delivery	Does not affect the ability to deliver SJC water to contractors. No change in the way the reservoir is operated for natural flow.	X	
		Winter flows	Allows for higher winter flows below El Vado in November and December. SJC water would be delivered in November and December. Lower flows below El Vado in January and February.	X	
		Conservation storage	Does not allow for additional storage space in El Vado and Abiquiu. SJC water delivered before snowmelt runoff season.	X	
		Conservation storage	Contractors do not suffer evaporation losses until the water is released.	X	
		Reservoir levels	Less stable lake levels downstream since water is not delivered throughout the year. Delivery of SJC water would be November and December. Exception could be MRGCD Water delivery. Payback to river would be bypassed.	X	
		Channel capacities	No impact to channel capacities	X	
		Rio Grande Compact	There should be no impact to NM's capability to meet Rio Grande Compact obligations.	X	
		Low flow conveyance channel	Should have no impact on low flow conveyance channel operation	X	
		Reservoir levels	More stable lake levels at Heron throughout most of the year.	X	
		Rafting flows	There should be no impact to rafting flows	X	
Heron	Waivers - April 30	Water delivery	Does not affect the ability to deliver SJC water to contractors. No change in the way the reservoir is operated for natural flow.	X	
		Winter flows	Allows for higher winter flows below El Vado. SJC water could be delivered November through April.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Conservation storage	Does not allow for additional storage space in El Vado and Abiquiu. SJC water delivered before snowmelt runoff season.	X	
		Conservation storage	Contractors do not suffer evaporation losses until the water is released.	X	
		Reservoir levels	Less stable lake levels downstream since water is not delivered throughout the year. Delivery of SJC water would be November and December. Exception could be MRGCD Water delivery. Payback to river would be bypassed.	X	
		Channel capacities	No impact to channel capacities.	X	
		Rio Grande Compact	There should be no impact to NM's capability to meet Rio Grande Compact obligations.	X	
		Low flow conveyance channel	Should have no impact on low flow conveyance channel operation	X	
		Reservoir levels	More stable lake levels at Heron throughout most of the year.	X	
		Rafting flows	There should be no impact to rafting flows.	X	
Heron	Waivers - June 30	Water delivery	Could affect the ability to deliver SJC water to contractors. No change in the way the reservoir is operated for natural flow. Possible disadvantage that contractors might consider in deciding whether to utilize such a waiver is the possibility that El Vado could be at channel capacity bypassing natural flow in May and June and not be able to make SJC water deliveries.	X	
		Winter flows	Could have lower SJC flows below El Vado from November to June.	X	
		Conservation storage	Does not allow for additional storage space in El Vado and Abiquiu. SJC water is delivered during snowmelt runoff season	X	
		Conservation storage	Contractors do not suffer evaporation losses until the water is released.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Reservoir levels	Less stable lake levels downstream since water is not delivered throughout the year. Delivery of SJC water would be June. Exception could be MRGCD Water delivery. Payback to river would be bypassed.	X	
		Channel capacities	No impact to channel capacities.	X	
		Rio Grande Compact	Potential impact to NM's ability to meet Compact obligations, particularly in year of early run-off (if waiver results in greater MRGCD use of native water.)	X	
		Low flow conveyance channel	Should have no impact on low flow conveyance channel operation	X	
		Reservoir levels	More stable lake levels at Heron throughout most of the year.	X	
		Rafting flows	No impact to rafting flows	X	
Heron	Waivers - August 31	Water delivery	Does not affect the ability to deliver SJC water to contractors.	X	
		Winter flows	Could have lower SJC flows below El Vado during the winter.	X	
		Conservation storage	Does allow for additional storage space in El Vado and Abiquiu. SJC water is delivered after snowmelt runoff season.	X	
		Conservation storage	Contractors do not suffer evaporation losses until the water is released.	X	
		Reservoir levels	Could have more stable lake levels downstream since water is delivered during the irrigation season. Exception could be payback to river, which could be bypassed.	X	
		Channel capacities	Could impact channel capacities releases because of the additional water stored upstream	X	
		Rio Grande Compact	Likely impact to NM's ability to meet Rio Grande Compact obligations if water is stored for other purposes other then compact deliveries.	X	
		Low flow conveyance channel	Should have no impact on low flow conveyance channel operation	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Reservoir levels	More stable lake levels at Heron throughout most of the year.	X	
		Rafting Flows	Could have higher rafting flows.	X	
Heron	Waivers - September 30	Water delivery	Does not affect the ability to deliver SJC water to contractors.	X	
		Winter flows	Could have lower SJC flows below El Vado during the winter.	X	
		Conservation storage	Does allow for additional storage space in El Vado and Abiquiu. SJC water is delivered after snowmelt runoff season.	X	
		Conservation storage	Contractors do not suffer evaporation losses until the water is released.	X	
		Reservoir levels	Could have more stable lake levels downstream since water is delivered during the irrigation season. Exception could be payback to river, which could be bypassed.	X	
		Channel capacities	Could impact channel capacities releases because of the additional water stored upstream	X	
		Rio Grande Compact	Would diminish NM's capability to meet Rio Grande Compact obligations if water is stored for other purposes other then compact deliveries	X	
		Low flow conveyance channel	Should have no impact on low flow conveyance channel operation	X	
		Reservoir levels	More stable lake levels at Heron throughout most of the year.	X	
		Rafting flows	Could have higher rafting flows.	X	
Abiquiu	20,000-acre-foot Conservation Storage	Irrigation demand	Does not affect the ability to release or pass water through Abiquiu to meet MRGCD irrigation demands. All demands downstream from Abiquiu need to be met before storage can take place.	X	
		Water delivery	Does not affect the ability to release San Juan-Chama water under existing laws. Natural flow into Abiquiu is the first water to be released or evacuated.	X	
		Flooding	Does not affect overbank flooding	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flooding	Does not affect low flow velocity	X	
		Flood control	Level of protection for flood control remains the same. Storage takes place within existing San Juan-Chama pool (elev. 6,220).	X	
		Pool elevations	Higher pool elevations as a result of the storage of native water do not impact the rafting take out point (elev. 6,237).	X	
		Water delivery	Should not decrease the ability to move SJC water into storage during irrigation season and therefore not affect rafting releases.	X	
		Reservoir levels	Could have more fluctuation in reservoir levels during spring runoff.	X	
		Reservoir levels	Higher pool elevations during the irrigation season.	X	
		Peak discharge	There could be a slight reduction in peak discharge from Cochiti. Releases from Abiquiu could be increased when main stem of the Rio Grande is peaking to reduce impact.	X	
		Peak discharge	There could be a slight reduction in peak discharges below Abiquiu. Releases from Abiquiu could be increased up to channel capacity when main stem of the Rio Grande is peaking.	X	
		Narrowing of River Channel	Not likely to affect narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge.	X	
		Maintenance flows	Should not impact maintenance flows required by riparian ecosystem.	X	
		Sediment transport	Slight reduction in the ability to transport sediment through the system when conservation storage is taking place.	X	
		Spawning flows	There should be no reduction in spawning flows. Conservation storage would only take place when all needs are met.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Spawning flows	Could have the ability to manufacture a spawning flow with SJC water.	X	
		Rio Grande Compact	Likely impact to NM's ability to meet Rio Grande Compact obligations if water is stored for other purposes other then compact deliveries. May require mitigation.	X	
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation.	X	
		Floodplain encroachment	Should have no increase in encroachment (houses) in the floodplain.	X	
		Winter flows	Higher winter flows from November to March below Abiquiu if water is released during this time frame.	X	
		Pool elevations	More stable pools during the recreation season. If the water is released in November to March.	X	
		Bank erosion	Reduces bank sloughing because of lower releases while conservation storage is taking place.	X	
		Carryover storage	Decreases the chance for carryover storage at Cochiti. Water held upstream in Abiquiu Reservoir.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
Abiquiu	50,000-acre-foot Conservation Storage	Irrigation demand	Does not affect the ability to release or pass water through Abiquiu to meet MRGCD irrigation demands. All demands downstream from Abiquiu need to be met before storage can take place.	X	
		Water delivery	Does not affect the ability to release San Juan-Chama water under existing laws. Natural flow into Abiquiu is the first water to be released or evacuated.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flooding	Could affect overbank flooding below Abiquiu and Middle Rio Grande Valley. To reduce impact releases from Abiquiu could be increased to match peak flow on main stem.	X	
		Flooding	Could affect low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley. To reduce impact releases from Abiquiu could be increased to match peak flow on main stem	X	
		Flood control	Level of protection for flood control remains the same. Storage takes place within existing San Juan-Chama pool (elev. 6,220).	X	
		Water delivery	Could decrease the ability to move SJC water into storage during irrigation season and therefore affect rafting releases. This could occur if main stem flows and MRGCD (El Vado) releases are enough to meet demand.	X	
		Pool elevations	Higher pool elevations as a result of the storage of native water do not impact the rafting take out point (elev. 6,237).	X	
		Reservoir levels	Could have more fluctuation in reservoir levels during spring runoff.	X	
		Reservoir levels	Higher pool elevations during the irrigation season.	X	
		Pool elevations	Higher pool elevations during recreation season.	X	
		Peak discharge	Reduction in duration of peak discharge from Cochiti. Releases from Abiquiu could be increased when main stem of the Rio Grande is peaking to reduce impact.	X	
		Peak discharge	Reduction in duration of peak discharges below Abiquiu. Releases would be increased for a short time to match peak on main stem of Rio Grande.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Narrowing of channel	Likely to affect narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge if done every year.	X	
		Narrowing of channel	Conservation storage of this magnitude should have no effect on narrowing of river channel if done every three years.	X	
		Maintenance flows	Reduction in maintenance flows required by riparian ecosystem.	X	
		Sediment transport	Reduction in the ability to transport sediment through the system when conservation storage is taking place.	X	
		Spawning flows	There should be no reduction in spawning flows. Conservation storage would only take place when all needs are met.	X	
		Spawning flows	Could have the ability to manufacture a spawning flow with SJC water.	X	
		Rio Grande Compact	Likely impact to NM's ability to meet Rio Grande Compact obligations if water is stored for other purposes other then compact deliveries. May require mitigation.	X	
		Rio Grande Compact	.Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation.	X	
		Narrowing of channel	Should have no increase in encroachment (houses) in the floodplain.	X	
		Winter flows	Higher winter flows from November to March below Abiquiu if water is released during this time frame.	X	
		Pool elevations	More stable pools during the recreation season if water is released from November to March.	X	
		Bank erosion	Reduces bank sloughing because of lower releases while conservation storage is taking place.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Carryover storage	Decreases the chance for carryover storage at Cochiti. Water held upstream in Abiquiu Reservoir.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
Abiquiu	100,000-acre-foot Conservation Storage	Irrigation demand	Does not affect the ability to release or pass water through Abiquiu to meet MRGCD irrigation demands. All demands downstream from Abiquiu need to be met before storage can take place.	X	
		Water delivery	Does not affect the ability to release San Juan-Chama water under existing laws. Natural flow into Abiquiu is the first water to be released or evacuated.	X	
		Flooding	Does affect overbank flooding below Abiquiu and Middle Rio Grande Valley. To reduce impact releases from Abiquiu could be increased to match peak flow on main stem.	X	
		Flooding	Could affect low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley. To reduce impact releases from Abiquiu could be increased to match peak flow on main stem.	X	
		Flood control	Level of protection for flood control remains the same. Storage takes place within existing San Juan-Chama pool (elev. 6,220).	X	
		Water delivery	Could decrease the ability to move SJC water into storage during and after irrigation season. Rafting releases could be affected. This could occur if main stem flows and MRGCD (El Vado) releases are enough to meet demand.	X	
		Pool elevations	Higher pool elevations as a result of the storage of native water do not impact the rafting take out point (elev. 6,237).	X	
		Reservoir levels	Could have more fluctuation in reservoir levels during spring runoff	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Reservoir levels	Higher pool elevations during the irrigation season.	X	
		Pool elevations	Higher pool elevations during recreation season.	X	
		Peak discharge	Reduction in peak discharge from Cochiti. May require mitigation.	X	
		Peak discharge	Reduction in peak discharges below Abiquiu.	X	
		Narrowing of channel	Likely to affect narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge if done every year. May require mitigation.	X	
		Narrowing of channel	Conservation storage of this magnitude should have no effect on narrowing of river channel if done every five to seven years	X	
		Maintenance flows	Reduction in maintenance flows required by riparian ecosystem. May require mitigation.	X	
		Sediment transport	Reduction in the ability to transport sediment through the system when conservation storage is taking place.	X	
		Spawning flows	There should be no reduction in spawning flows. Conservation storage would only take place when all needs are met.	X	
		Spawning flows	Could have the ability to manufacture a spawning flow with SJC water.	X	
		Rio Grande Compact	Likely impact to NM's ability to meet Rio Grande Compact obligations if water is stored for other purposes other then compact deliveries. May require mitigation.	X	
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation	X	
		Narrowing of channel	Could have an increase in encroachment (houses) in the floodplain with the lower releases when conservation storage is taking place.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Winter flows	Higher winter flows from November to March below Abiquiu if water is released during this time frame.	X	
		Pool elevations	More stable pools during the recreation season if water is released from November to March.	X	
		Bank erosion	Reduces bank sloughing because of lower releases while conservation storage is taking place.	X	
		Carryover storage	Decreases the chance for carryover storage at Cochiti.	X	
		Low flow conveyance channel	Could impact low flow conveyance channel operation.	X	
Abiquiu	Up to elevation 6,220 (183,000 acre-feet) Conservation Storage	Irrigation demand	Does not affect the ability to release or pass water through Abiquiu to meet MRGCD irrigation demands. All demands downstream from Abiquiu need to be met before storage can take place.	X	
		Water delivery	Does not affect the ability to release San Juan-Chama water under existing laws. Natural flow into Abiquiu is the first water to be released or evacuated.	X	
		Flooding	Does affect overbank flooding below Abiquiu and Middle Rio Grande Valley. To reduce impact releases from Abiquiu could be increased to match peak flow on main stem.	X	
		Flooding	Could affect low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley. To reduce impact releases from Abiquiu could be increased to match peak flow on main stem.	X	
		Flood control	Level of protection for flood control remains the same. Storage takes place within existing San Juan-Chama pool (elev. 6220).	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Water delivery	Decreases the ability to move SJC water into storage during and after irrigation season. Rafting releases could be affected. This could occur if main stem flows and MRGCD (El Vado) releases are enough to meet demand.	X	
		Pool elevations	Higher pool elevations as a result of the storage of native water do not impact the rafting take out point (elev. 6237).	X	
		Reservoir levels	Could have more fluctuation in reservoir levels during spring runoff and irrigation season months. Higher pool elevations during the irrigation season. Depends on the rate the water is used.	X	
		Reservoir levels	Higher pool elevations during recreation season.	X	
		Pool elevations	Higher pool elevations during recreation season.	X	
		Peak discharge	Reduction in peak discharge from Cochiti. May limit applicability or require mitigation	X	
		Peak discharge	Reduction in peak discharges below Abiquiu. May limit applicability or require mitigation	X	
		Narrowing of channel	Likely to affect narrowing of river channel (Rio Champ and Rio Grande) due to long-term reduction in channel forming discharge. May limit applicability or require mitigation	X	
		Maintenance flows	Reduction in maintenance flows required by riparian ecosystem. May limit applicability or require mitigation	X	
		Sediment transport	Reduction in the ability to transport sediment through the system when conservation storage is taking place. May limit applicability or require mitigation	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Spawning flows	There should be no reduction in spawning flows. Conservation storage would only take place when all needs are met.	X	
		Spawning flows	Could have the ability to manufacture a spawning flow with SJC water. May require mitigation.	X	
		Rio Grande Compact	Likely impact to Rio Grande Compact obligations if water is stored for other purposes other then compact deliveries. May require mitigation.	X	
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation.	X	
		Narrowing of channel	Could have an increase in encroachment (houses) in the floodplain with the lower releases when conservation storage is taking place.	X	
		Winter flows	Higher winter flows from November to March below Abiquiu if water is released during this time frame.	X	
		Pool elevations	More stable pools during the recreation season if water is released from November to March.	X	
		Bank erosion	Reduces bank sloughing because of lower releases while conservation storage is taking place.	X	
		Carryover storage	Decreases the chance for carryover storage at Cochiti.	X	
		Low flow conveyance channel	Could impact low flow conveyance channel operation.	X	
Abiquiu	600-cfs Channel Capacity	Irrigation demand	Affects the ability to release or pass water through Abiquiu to meet MRGCD irrigation demand. Historical operations during the irrigation show that MRGCD would not be able to meet demand.		X

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Water delivery	Affects the ability to release San Juan-Chama water under existing laws. Natural flow into Abiquiu is the first water to be released or evacuated. SJC water would have to be released during winter months. Affects the ability to deliver water to Elephant Butte Reservoir.		X
		Pool elevations	Higher pool elevations as a result of the lower channel capacity could affect the rafting take out point (elev. 6,237).		
		Fluctuation in reservoir levels	More fluctuation in reservoir levels during spring runoff and winter months. Higher pool elevations during the irrigation season.	X	
		Flooding	Reduction in overbank flooding below Abiquiu and Middle Rio Grande Valley.		
		Flooding	Reduction in low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley.		
		Peak Discharge	Reduction in peak discharge from Cochiti.		
		Narrowing of river channel	Narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge.		
		Maintenance flows	Reduction in maintenance flows required by riparian ecosystem		X
		Flood control	Decrease in the level of protection for flood control as a result of the decrease in channel capacity.		X
		Sediment transport	Reduction in the ability to transport sediment through the system resulting in sediment plugs.		X
		Spawning flows	Reduction in spawning flows. Release of native flow limited by channel capacity.		
		Spawning flows	Would not have the ability to manufacture a spawning flow with SJC water.		X
		Rio Grande Compact	Likely impact to Rio Grande Compact obligations. Water held up because of the lower channel capacity.		X

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation.	X	
		Carry-over water	Increase in the number of years where the Corps would have carry-over water.	X	
		Conservation water	Increases the ability to store conservation water. Downstream minimum flow during conservation storage could be higher then 150-200 cfs range.	X	
		Encroachment in the floodplain	Increase in encroachment (houses) in the floodplain.		
		Winter flows	Could have higher winter flows from November to March if we have carry-over storage and water is released during this time frame.	X	
		Pools during the recreation season	More stable pools during the recreation season. MRGCD demand could be met with releases from El Vado. There would be no need to fluctuate the pool at Abiquiu.	X	
		Hydropower	Decreases peak hydropower generation. Could extent period when generating power. Flow could go through one unit.		
		Bank erosion	Reduces bank sloughing.	X	
		Reproduction of non-native plants	Increases reproduction of non-native plants on exposed banks and riverbed.		
		Low flow conveyance channel	Could impact low flow conveyance channel operation.		
		ESA compliance	Channel capacity reached earlier than existing condition. There would be no SJC releases during this time frame. If all demands are being met downstream the city of the Albuquerque could divert from the Rio Grande and payback the river with SJC at a later date. (July-September). Would add flow during the summer months for ESA compliance	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Channel capacity	Based on historical records (1975-1999) channel capacity of 600 cfs would be reached 100 percent of the time.		
Abiquiu	800-cfs Channel Capacity	Irrigation demand	Affects the ability to release or pass water through Abiquiu to meet MRGCD irrigation demand. Historical operations during the irrigation show that MRGCD would not be able to meet demand. Would require more efficient MRGCD operations, i.e. reduced diversion demand		X
		Water delivery	Affects the ability to release San Juan-Chama water under existing laws. Natural flow into Abiquiu is the first water to be released or evacuated. SJC water would have to be released during winter months. Affects ability to deliver water to Elephant Butte Reservoir.		X
		Pool elevations	Higher pool elevations as a result of the lower channel capacity could affect the rafting take out point (elev. 6,237). The higher the channel capacity the less impact on the rafting takeout.	X	
		Fluctuation in reservoir levels	More fluctuation in reservoir levels during spring runoff and winter months. Higher pool elevations during the irrigation season.	X	
		Flooding	Reduction in overbank flooding below Abiquiu and Middle Rio Grande Valley.		
		Flooding	Reduction in low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley.		
		Peak Discharge	Reduction in peak discharge from Cochiti.		
		Narrowing of River Channel	Narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge.		
		Maintenance flows	Reduction in maintenance flows required by riparian ecosystem.		

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flood control	Decrease in the level of protection for flood control as a result of the decrease in channel capacity.		
		Sediment transport	Reduction in the ability to transport sediment through the system resulting in sediment plugs.		
		Spawning flows	Reduction in spawning flows. Release of native flow limited by channel capacity.		X
		Spawning flows	Would not have the ability to manufacture a spawning flow with SJC water.		X
		Rio Grande Compact	Likely impact to NM's ability to meet Rio Grande Compact obligations. Water held up because of the lower channel capacity. Might require mitigation measures		X
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation. Water could be released during the winter months for compact deliveries	X	
		Carryover storage	Increase in the number of years where the Corps would have carryover water. Higher channel capacity decreases the chances for carry-over water.	X	
		Conservation water	Increases the ability to store conservation water. Downstream minimum flow during conservation storage could be higher then 150-200 cfs range.	X	
		Encroachment in the floodplain	Increase in encroachment (houses) in the floodplain.		
		Winter flows	Could have higher winter flows from November to March if we have carry-over storage and water is released during this time frame.	X	
		Pool elevations	More stable pools during the recreation season. Less fluctuation in pool elevation demand could be met with releases from El Vado.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Hydropower	Decreases peak hydropower generation. Could extent period when generating power. Flow could go through one unit.		
		Bank erosion	Reduces bank sloughing.	X	
		Bank vegetation	Increases reproduction of non-native plants on exposed banks and riverbed.		
		Low flow conveyance channel	Could impact low flow conveyance channel operation.		
		ESA compliance	Channel capacity reached earlier than existing condition. There would be no SJC releases during this time frame. If all demands are being met downstream the city of the Albuquerque could divert from the Rio Grande and payback the river with SJC at a later date. (July-September). Would add flow during the summer months for ESA compliance	X	
		Channel capacity	Based on historical records (1975-1999) channel capacity would be reached 100 percent of the time.	X	
Below Abiquiu	1,200-cfs Channel Capacity	Irrigation Demand	Does not affect the ability to release or pass water through Abiquiu to meet MRGCD irrigation demand. Historical operations during the irrigation show that MRGCD would be able to meet demand.	X	
		Water delivery	Affects the ability to release San Juan-Chama water under existing laws. Natural flow into Abiquiu is the first water to be released or evacuated. The higher channel capacity improves the ability to move SJC during the irrigation. Could affect ability to deliver water to Elephant Butte Reservoir.	X	
		Pool elevations	Higher pool elevations as a result of the lower channel capacity could affect the rafting take out point (elev. 6,237). The higher the channel capacity the less impact on the rafting takeout.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Reservoir levels	More fluctuation in reservoir levels during spring runoff and winter months. Higher pool elevations during the irrigation season. The higher channel capacity dampens the fluctuation during the months stated above.	X	
		Flooding	Reduction in overbank flooding below Abiquiu and Middle Rio Grande Valley. Higher increase in channel capacity increases the chances of overbank flooding.		
		Flooding	Reduction in low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley. Higher increase in channel capacity increases the chances of low flow velocity in overbanks.		
		Peak discharge	Reduction in peak discharge from Cochiti. Higher channel capacity improves the chances of Cochiti making channel capacity releases.		
		Narrowing of channel	Narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge.		
		Maintenance flows	Reduction in maintenance flows required by riparian ecosystem.		
		Flood control	Decrease in the level of protection for flood control as a result of the decrease in channel capacity. Higher channel capacity increases the level of protection for areas below the dam.		
		Sediment transport	Reduction in the ability to transport sediment through the system resulting in sediment plugs. Sediment transport would likely be ok given this channel capacity on the Rio Chama but is most likely not sufficient for main stem of the Rio Grande.	X	
		Spawning flows	Slight reduction in spawning flows. Release of native flow limited by channel capacity. Historical operation for spawning flows was to increase release to 1,500 cfs.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Spawning flows	Should have the ability to manufacture a spawning flow with SJC water.	X	
		Rio Grande Compact	Likely impact to Rio Grande Compact obligations. Water held up because of the lower channel capacity. May require mitigation	X	
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation. . Water could be released during the winter months for compact deliveries	X	
		Carryover storage	Increase in the number of years where the Corps would have carry-over water. Higher channel capacity decreases the chances for carry-over water.	X	
		Conservation storage	Increases the ability to store conservation water. Downstream minimum flow would have to set between 150-200 cfs.	X	
		Encroachment in the floodplain	Starts to limit encroachment on the Rio Chama.	X	
		Winter flows	Could have higher winter flows from November to March if we have carry-over storage and water is released during this time frame.	X	
		Pool elevations	Stable pools during the recreation season decrease. Both Abiquiu and El Vado can now be used more efficient as source of Water delivery.	X	
		Hydropower	Decreases peak hydropower generation. Could extent period when generating power. Flow could go through one unit.	X	
		Bank erosion	Increases bank sloughing.		
		Bank vegetation	Starts to decrease reproduction of non-native plants on exposed banks and riverbed.	X	
		Low flow conveyance channel	Could impact low flow conveyance channel operation.		

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		ESA compliance	Channel capacity reached earlier than existing condition. There would be no SJC releases during this time frame. If all demands are being met downstream the city of the Albuquerque could divert from the Rio Grande and payback the river with SJC at a later date. (July-September). Would add flow during the summer months for ESA compliance	X	
		Channel capacity	Based on historical record (1975-1999) channel capacity would be reached 96 percent of the time.	X	
Below Abiquiu	1,500-cfs Channel Capacity	Irrigation demand	Does not affect the ability to release or pass water through Abiquiu to meet MRGCD irrigation demand.	X	
		Water delivery	Higher channel capacity improves the ability to move SJC during the irrigation season. Natural flow into Abiquiu is the first water to be released or evacuated. Could affect ability to deliver water to Elephant Butte Reservoir.	X	
		Pool elevations	Higher pool elevations as a result of the lower channel capacity could affect the rafting take out point (elev. 6,237). The higher the channel capacity the less impact on the rafting takeout.	X	
		Reservoir levels	Starts to dampen fluctuation in reservoir levels during spring runoff and winter months. Higher pool elevations during the irrigation season. Higher channel capacity dampens the fluctuation during the months stated above.	X	
		Flooding	Could increase overbank flooding below Abiquiu and Middle Rio Grande Valley. Higher increase in channel capacity increases the chances of overbank flooding.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flooding	Could start to see an increase in low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley. Higher increase in channel capacity increases the chances of low flow velocity in the overbanks.	X	
		Peak discharge	Increases peak discharge from Cochiti. Higher channel capacity improves the chances of Cochiti making channel capacity releases.	X	
		Narrowing of channel	Helps to control narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge.	X	
		Maintenance flows	Could help provided maintenance flows required by riparian ecosystem.	X	
		Flood control	Decrease in the level of protection for flood control as a result of the decrease in channel capacity. Higher channel capacity increases the level of protection for areas below the dam.	X	
		Sediment transport	Not likely to impact the ability to transport sediment through the system.	X	
		Spawning flows	Channel capacity releases could be used to add flow for spawning purposes. Higher channel capacity helps in the ability to manufacture a spawning flow. Under present operations would more then likely max out with a release of 1500 cfs for a spawning flow.	X	
		Spawning flows	Should have the ability to manufacture a spawning flow with SJC water.	X	
		Rio Grande Compact	Would there be less evaporation and transportation losses if water were held upstream.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation.. Water could be released during the winter months for compact deliveries	X	
		Carryover storage	Increase in the number of years where the Corps would have carry-over water. Higher channel capacity decreases the chances for carry-over water.	X	
		Conservation storage	Increases the ability to store conservation water. Downstream minimum flow would have to set between 150 – 200 cfs. Normal max release from Abiquiu is 1,800 cfs.	X	
		Encroachment in the floodplain	Starts to limit encroachment on the Rio Chama.	X	
		Winter flows	Could have higher winter flows from November to March if we have carry-over storage and water is released during this time frame. Higher channel capacity decreases winter flows but would still be above most historical flows.	X	
		Pool elevations	Stable pools during the recreation season decrease. Both Abiquiu and El Vado can now be used more efficient as source of Water delivery.	X	
		Hydropower	Decreases peak hydropower generation. Could extent period when generating power. Need two units operating to pass flow.	X	
		Bank erosion	Increases bank sloughing.		
		Bank vegetation	Decrease in reproduction of non-native plants on exposed banks and riverbed.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		ESA compliance	Channel capacity reached earlier then existing condition. There would be no SJC releases during this time frame. If all demands are being met downstream the city of the Albuquerque could divert from the Rio Grande and payback the river with SJC at a later date. (July-September). Would add flow during the summer months for ESA compliance.	X	
		Channel capacity	Based on historical record (1975-1999) channel capacity would be reached 80 percent of the time.	X	
Below Abiquiu	1,800-cfs Channel Capacity	Irrigation demand	Does not affect the ability to release or pass water through Abiquiu to meet MRGCD irrigation demand.	X	
		Water delivery	Higher channel capacity improves the ability to move SJC during the irrigation season. Natural flow into Abiquiu is the first water to be released or evacuated. Does not affect ability to deliver water to Elephant Butte.	X	
		Pool elevations	Lower pool elevations as a result of the higher channel capacity could impact the rafting take out point (elev. 6,237). The higher the channel capacity the less impact on the rafting takeout. Historically the pool has been above the rafting takeout three times during the rafting season.	X	
		Reservoir levels	Dampens fluctuation in reservoir levels during spring runoff and winter months. Lower pool elevations during the irrigation season. Higher channel capacity dampens the fluctuation during the months stated above.	X	
		Flooding	Increase in overbank flooding below Abiquiu and Middle Rio Grande Valley. Higher increase in channel capacity increases the chances of overbank flooding.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flooding	Increase in low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley. Higher increase in channel capacity increases the chances of low flow velocity in the overbanks.	X	
		Peak discharge	Increases peak discharge from Cochiti. Higher channel capacity improves the chances of Cochiti making channel capacity releases.	X	
		Narrowing of channel	Helps to control narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge.	X	
		Maintenance flows	Helps provide maintenance flows required by riparian ecosystem.	X	
		Flood control	No change in existing channel capacity means the level of protection for the project remains the same.	X	
		Sediment transport	No change in ability to transport sediment through the system.	X	
		Spawning flows	Channel capacity releases could be used to add flow for spawning purposes. Higher channel capacity helps in the ability to manufacture a spawning flow. Under present operations would more then likely max out with a release of 1,500 cfs for a spawning flow.	X	
		Spawning flows	Should have the ability to manufacture a spawning flow with SJC water.	X	
		Rio Grande Compact	No change in delivery of water for compact obligations.	X	
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation.		
		Carryover storage	No change in the number of years where the Corps would have carry-over water. Higher channel capacity decreases the chances for carry-over water.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Conservation storage	Still have the ability to store conservation water. Downstream minimum flow would have to set between 150-200 cfs.	X	
		Encroachment in the floodplain	Limits encroachment (houses) in the floodplain.	X	
		Winter flows	Could have higher winter flows from November to March if we have carry-over storage and water is released during this time frame. Higher channel capacity decreases the chance for carryover storage thereby decreasing winter flows.	X	
		Pool elevations	Stable pools during the recreation season decrease. Both Abiquiu and El Vado can now be used more efficient as source of Water delivery.	X	
		Hydropower	Helps with peak hydropower generation. Two units in operation.	X	
		Bank erosion	Increases bank sloughing.	X	
		Irrigation structures	Possible damage to rock and brush diversions.		
		Bank vegetation	Decrease reproduction of non-native plants on exposed banks and riverbed.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
		Channel capacity	Channel capacity reached during snowmelt runoff. There would be no SJC releases during this time frame. If all demands are being met downstream the city of the Albuquerque could divert from the Rio Grande and payback the river with SJC at a later date. (July-September). Would add flow during the summer months for ESA compliance.	X	
		Channel capacity	Based on historical record (1975-1999) channel capacity would be reached 72 percent of the time.	X	
Below Abiquiu	2,000-cfs Channel Capacity	Irrigation demand	Does not affect the ability to release or pass water through Abiquiu to meet MRGCD irrigation demand.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Water delivery	Higher channel capacity improves the ability to move SJC during the irrigation season. Natural flow into Abiquiu is the first water to be released or evacuated. Does not affect ability to deliver water to Elephant Butte.	X	
		Pool elevations	Lower pool elevations as a result of the higher channel capacity could impact the rafting take out point (elev. 6,237). The higher the channel capacity the less impact on the rafting takeout.	X	
		Reservoir levels	Dampens fluctuation in reservoir levels during spring runoff. Lower pool elevations during the irrigation season. Higher channel capacity dampens the fluctuation during the months stated above.	X	
		Flooding	Increase in overbank flooding below Abiquiu and Middle Rio Grande Valley. Higher channel capacity increases the overbank flooding.	X	
		Flooding	Increase in low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley. Higher channel capacity increases the chance for low flow velocity in the overbanks.	X	
		Peak discharge	Increases peak discharge from Cochiti. Higher channel capacity improves the chances of Cochiti making channel capacity releases.	X	
		Narrowing of channel	Helps to control narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge.	X	
		Maintenance flows	Does not limit potential for maintenance flows required by riparian ecosystem.	X	
		Flood control	Increase in the level of protection for flood control for areas below the dam as a result of the higher channel capacity. .	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Sediment transport	Increase in the ability to transport sediment through the system.	X	
		Spawning flows	Channel capacity releases could be used to add flow for spawning purposes. Higher channel capacity helps in the ability to manufacture a spawning flow. Under present operations would more then likely max out with a release of 1,500 cfs for a spawning flow.	X	
		Spawning flows	Should have the ability to manufacture a spawning flow with SJC water.	X	
		Rio Grande Compact	May impact NM's ability to meet Rio Grande Compact obligations. Potential exists for increase in delivery with the higher channel capacity.	X	
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation. Water could be released during the winter months for compact deliveries. Potential for decrease in the amount of water that would get caught up in Abiquiu.	X	
		Carryover storage	Decreases the number of years where the Corps would have carry-over water. Higher channel capacity decreases the chances for carry-over water.	X	
		Conservation storage	Still have the ability to store conservation water. Downstream minimum flow would have to set between 150-200 cfs.	X	
		Encroachment in the floodplain	Limits encroachment (houses) in the floodplain.	X	
		Winter flows	Could have higher winter flows from November to March if we have carry-over storage and water is released during this time frame. Higher channel capacity decreases the chance for carryover storage thereby decreasing winter flows.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Pool elevations	Stable pools during the recreation season decrease. Both Abiquiu and El Vado can now be used more efficient as source of Water delivery.	X	
		Hydropower	Increases peak hydropower generation. Two units in operation.	X	
		Bank erosion	Increases bank sloughing.		
		Irrigation structures	Damage to rock and brush diversions.		X
		Bank vegetation	Decreases the reproduction of non-native plants on exposed banks.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
		Channel capacity	Based on historical record (1975-2000) channel capacity was reached 28 percent of the time. From 1980 to 1991 was the only time that Abiquiu was operated to release more then 1,800 cfs channel capacity.	X	
Below Abiquiu	2,500-cfs Channel Capacity	Irrigation demand	Does not affect the ability to release or pass water through Abiquiu to meet MRGCD irrigation demand.	X	
		Water delivery	Higher channel capacity improves the ability to move SJC during the irrigation season. Natural flow into Abiquiu is the first water to be released or evacuated. Does not affect ability to deliver water to Elephant Butte.	X	
		Pool elevations	Lower pool elevations as a result of the higher channel capacity could impact the rafting take out point (elev. 6,237). The higher the channel capacity the less impact on the rafting takeout.	X	
		Reservoir levels	Dampens fluctuation in reservoir levels during spring runoff. Lower pool elevations during the irrigation season. Higher channel capacity dampens the fluctuation during the months stated above.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flooding	Increase in overbank flooding below Abiquiu and Middle Rio Grande Valley. Higher channel capacity increases the overbank flooding.	X	
		Flooding	Increase in low flow velocity in the overbanks below Abiquiu and Middle Rio Grande Valley. Higher channel capacity increases the chance for low flow velocity in the overbanks.	X	
		Peak discharge	Increases peak discharge from Cochiti. Higher channel capacity improves the chances of Cochiti making channel capacity releases.	X	
		Narrowing of River Channel	Helps to control narrowing of river channel (Rio Chama and Rio Grande) due to long-term reduction in channel forming discharge.	X	
		Maintenance flows	Provides maintenance flows required by riparian ecosystem.	X	
		Flood control	Increase in the level of protection for flood control for areas below the dam as a result of the higher channel capacity	X	
		Sediment transport	Increase in the ability to transport sediment through the system.	X	
		Spawning flows	Channel capacity releases could be used to add flow for spawning purposes. Higher channel capacity helps in the ability to manufacture a spawning flow. Under present operations would more then likely max out with a release of 1500 cfs for a spawning flow.	X	
		Spawning flows	Should have the ability to manufacture a spawning flow with SJC water.	X	
		Rio Grande Compact	Potential for impact NM's ability to meet Rio Grande Compact obligations. Increase in potential delivery with the higher channel capacity.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation. Water could be released during the winter months for compact deliveries. Decrease in the amount of water that would get caught up in Abiquiu.	X	
		Carryover storage	Decreases the number of years where the Corps would have carry-over water. Higher channel capacity decreases the chances for carry-over water.	X	
		Conservation storage	Still have the ability to store conservation water. Downstream minimum flow would have to set between 150-200 cfs.	X	
		Encroachment in the floodplain	Limits encroachment (houses) in the floodplain.	X	
		Winter flows	Could have higher winter flows from November to March if we have carry-over storage and water is released during this time frame. Higher channel capacity decreases the chance for carryover storage thereby decreasing winter flows.	X	
		Pool elevations	Stable pools during the recreation season decrease. Both Abiquiu and El Vado can now be used more efficient as source of Water delivery.	X	
		Hydropower	Increases peak hydropower generation. Max release from two units in operation.	X	
		Bank erosion	Increases bank sloughing.		
		Irrigation structures	Damage to rock and brush diversions.		X
		Bank vegetation	Decreases the reproduction of non-native plants on exposed banks.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Channel capacity	Based on historical record (1975-2000) channel capacity was reached 8 percent of the time. From 1980 to 1991 was the only time that Abiquiu was operated to release more then 1,800 cfs channel capacity.	X	
Cochiti	5,000-cfs Channel Capacity	Irrigation demand	Does not affect the ability to release or pass water through Cochiti to meet MRGCD irrigation demand.	X	
		Water delivery	Affects the ability to release San Juan-Chama water under existing laws. Natural flow into Cochiti is the first water to be released or evacuated. SJC water would have to be released during winter months. Affects ability to deliver water to Elephant Butte Reservoir.		
		Fluctuation in reservoir levels	More fluctuation in reservoir levels during spring runoff and winter months. Possible higher pool elevations during the irrigation season. Could impact Cochiti delta and Bandolier Natural Park		X
		Flooding	Reduction in overbank flooding below Cochiti.		
		Flooding	Reduction in low flow velocity in the overbanks below Cochiti.		
		Narrowing of River Channel	Narrowing of river channel (Rio Grande) due to long-term reduction in channel forming discharge.		
		Maintenance flows	Reduction in maintenance flows required by riparian ecosystem.		
		Flood control	Decrease in the level of protection for flood control as a result of the decrease in channel capacity.		
		Sediment transport	Reduction in the ability to transport sediment through the system resulting in sediment plugs.		
		Spawning flows	There should be no reduction in spawning flows.		

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Rio Grande Compact	Likely impact to Rio Grande Compact obligations. Water held upstream because of the lower channel capacity.		
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation.. Water could be released during the winter months for compact deliveries.		
		Carry-over water	Increase in the number of years where the Corps would have carry-over water.		
		Conservation water	The lower channel capacity could increase the chance of storing water at Abiquiu.	X	
		Encroachment in the floodplain	Possible increase in encroachment (houses) in the floodplain.		
		Winter flows	Could have higher flows from November to March below Cochiti because of possible carryover storage.		
		Pools during the recreation season	Higher pools during the recreation season.	X	
		Bank erosion	Reduces bank sloughing.	X	
		Reproduction of non-native plants	Increases reproduction of non-native plants on exposed banks and riverbed.		
		Low flow conveyance channel	Should not impact low flow conveyance channel operation	X	
		Channel Capacity	Based on historical records (1975-1999) channel capacity of 5,000 cfs was reached 48 percent of the time. In some cases releases from Cochiti dictated by condition of channel downstream from dam and Elephant Butte storage. Percentage of the time Otowi was 5,000 cfs or above was 60 percent.	X	
Cochiti	7,000-cfs Channel Capacity	Irrigation demand	Does not affect the ability to release or pass water through Cochiti to meet MRGCD irrigation demand.	X	
		Water delivery	Not likely to affect the ability to release San Juan-Chama water under existing laws.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Fluctuation in reservoir levels	Less fluctuation in reservoir levels during spring runoff and winter months. Should have very little impact Cochiti Delta and Bandolier National Monument.	X	
		Flooding	Increase in overbank flooding below Cochiti.	X	
		Flooding	Increase in low flow velocity in the overbanks below Cochiti.	X	
		Narrowing of River Channel	Helps control narrowing of river channel (Rio Grande) due to long-term reduction in channel forming discharge.	X	
		Maintenance flows	Increase in maintenance flows required by riparian ecosystem.	X	
		Flood control	Increase in the level of protection for flood control as a result of the increase in channel capacity.	X	
		Sediment transport	Increase in the ability to transport sediment through the system.	X	
		Spawning flows	There should be no reduction in spawning flows.	X	
		Rio Grande Compact	Likely impact to NM's ability to meet Rio Grande Compact obligations. Increase in channel capacity helps delivery obligations.	X	
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation. Water could be released during the winter months for compact deliveries.	X	
		Carry-over storage	Decrease in the number of years where the Corps would have carry-over water. Higher channel capacity decreases chance for carry-over storage.		
		Conservation water	Should have no impact on storage of conservation water at Abiquiu.	X	
		Encroachment in the floodplain	Possible decrease in encroachment (houses) in the floodplain.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Winter flows	Normal flows from November to March without carryover storage. Pass inflow.	X	
		Pools during the recreation season	Normal pools during the recreation season.	X	
		Bank erosion	Increase in bank sloughing.		
		Reproduction of non-native plants	Decreases reproduction of non-native plants on exposed banks and riverbed.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
		Channel capacity	Based on historical records (1975-1999) channel capacity of 7000 cfs was reached 24 percent of the time. In some cases releases from Cochiti dictated by condition of channel downstream and Elephant Butte storage. Percentage of the time Otowi was 7000 cfs or above was 48 percent.	X	
Cochiti	8,000-cfs Channel Capacity	Irrigation demand	Does not affect the ability to release or pass water through Cochiti to meet MRGCD irrigation demand.	X	
		Water delivery	Does not affect the ability to release San Juan-Chama water under existing laws.	X	
		Fluctuation in reservoir levels	Less fluctuation in reservoir levels during spring runoff. Should have very little impact Cochiti Delta and Bandolier National Monument.	X	
		Flooding	Increase in overbank flooding below Cochiti.	X	
		Flooding	Increase in low flow velocity in the overbanks below Cochiti.	X	
		Narrowing of River Channel	Helps to control narrowing of river channel (Rio Grande) due to long-term reduction in channel forming discharge.	X	
		Maintenance flows	Increase in maintenance flows required by riparian ecosystem.	X	
		Flood control	Increase in the level of protection for flood control as a result of the increase in channel capacity.	X	
		Sediment transport	Increase in the ability to transport sediment through the system.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Spawning flows	There should be no reduction in spawning flows.	X	
		Rio Grande Compact	Likely impact to NM's ability to meet Rio Grande Compact obligations. Increase in channel capacity increases potential for conveying delivery obligations.	X	
		Carry-over storage	Decrease in the number of years where the Corps would have carry-over water. Higher channel capacity decreases chance for carry-over storage.	X	
		Conservation water	Should have no impact on storage of conservation water at Abiquiu.	X	
		Encroachment in the floodplain	Possible decrease in encroachment (houses) in the floodplain.	X	
		Winter flows	Normal flows from November to March without carryover storage. Pass inflow.	X	
		Pools during the recreation season	Normal pools during the recreation season.	X	
		Bank erosion	Increase in bank sloughing. Some streambank protection could be needed to pass the higher flows.		
		Reproduction of non-native plants	Decreases reproduction of non-native plants on exposed banks and riverbed.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
		Channel capacity	Based on historical records (1975-1999) channel capacity of 8,000 cfs was reached 12 percent of the time. In some cases releases from Cochiti dictated by condition of channel downstream and Elephant Butte storage. Percentage of the time Otowi was 8,000 cfs or above was 44 percent.	X	
Cochiti	10,000-cfs Channel Capacity	Irrigation demand	Does not affect the ability to release or pass water through Cochiti to meet MRGCD irrigation demand.	X	
		Water delivery	Does not affect the ability to release San Juan-Chama water under existing laws.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Pool elevations	Very little fluctuation in reservoir levels during spring runoff.	X	
		Fluctuation in reservoir levels	Less fluctuation in reservoir levels during spring runoff. Should have very little impact Cochiti Delta and Bandolier National Monument.	X	
		Flooding	Increase in overbank flooding below Cochiti.	X	
		Flooding	Increase in low flow velocity in the overbanks below Cochiti.	X	
		Narrowing of River Channel	Helps to control narrowing of river channel (Rio Grande) due to long-term reduction in channel forming discharge	X	
		Maintenance flows	Increase in maintenance flows required by riparian ecosystem.	X	
		Flood control	Increase in the level of protection for flood is needed control as a result of the increase in channel capacity.	X	
		Sediment transport sediment	Increase in the ability to transport sediment through the system.	X	
		Spawning flows	There should be no reduction in spawning flows.	X	
		Rio Grande Compact	Likely impact to Rio Grande Compact obligations. Increase in channel capacity provides potential for improvement in meeting delivery obligations.	X	
		Carry-over storage	Decrease in the number of years where the Corps would have carry-over water. Higher channel capacity decreases chance for carry-over storage.	X	
		Conservation water	Should have no impact on storage of conservation water at Abiquiu.	X	
		Encroachment in the floodplain	Possible decrease in encroachment (houses) in the floodplain.	X	
		Winter flows	Normal flows from November to March without carryover storage. Pass inflow.	X	
		Pools during the recreation season	Normal pools during the recreation season.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Bank erosion	Increase in bank sloughing. Some streambank protection could be needed to pass the higher flows.		
		Reproduction of non-native plants	Decreases reproduction of non-native plants on exposed banks and riverbed.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
		Channel capacity	Based on historical records (1975-1999) channel capacity of 10,000 cfs was reached 0 percent of the time. In some cases releases from Cochiti dictated by condition of channel downstream and Elephant Butte storage. Percentage of the time Otowi was 10,000 cfs or above was 8 percent.	X	
Cochiti	12,500-cfs Channel Capacity	Irrigation demand	Does not affect the ability to release or pass water through Cochiti to meet MRGCD irrigation demand.	X	
		Water delivery	Does not affect the ability to release San Juan-Chama water under existing laws.	X	
		Fluctuation in reservoir levels	Very little fluctuation in reservoir levels during spring runoff.	X	
		Flooding	Increase in overbank flooding below Cochiti.	X	
		Flooding	Increase in low flow velocity in the overbanks below Cochiti.	X	
		Narrowing of River Channel	Controls narrowing of river channel (Rio Grande) due to long-term reduction in channel forming discharge	X	
		Maintenance flows	Increase in maintenance flows required by riparian ecosystem.	X	
		Flood control	Increase in the level of protection for flood control as a result of the increase in channel capacity.	X	
		Sediment transport	Increase in the ability to transport sediment through the system.	X	
		Spawning flows	There should be no reduction in spawning flows.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Rio Grande Compact	Likely impact to Rio Grande Compact obligations. Increase in channel capacity potentially helps NM meet delivery obligations.	X	
		Carry-over storage	There should be no carry-over with the increased channel capacity.	X	
		Conservation water	Should have no impact on storage of conservation water at Abiquiu.	X	
		Encroachment in the floodplain	Possible decrease in encroachment (houses) in the floodplain.	X	
		Winter flows	Normal flows from November to March without carryover storage. Pass inflow.	X	
		Bank erosion	Increase in bank sloughing. Streambank protection would be needed to pass the higher flows from Cochiti to Elephant Butte. Possible water against the levees throughout most reaches. Bank sloughing of MRGCD facilities.		X
		Flooding	Possible flooding of irrigation land in the Cochiti to Bernalillo reach.		X
		Reproduction of non-native plants	Decreases reproduction of non-native plants on exposed banks and riverbed.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
		Channel capacity	Based on historical records (1975-1999) channel capacity of 12,500 cfs was reached 0 percent of the time. In some cases releases from Cochiti dictated by condition of channel downstream and Elephant Butte storage. Percentage of the time Otowi was 12,500 cfs or above was 4 percent.	X	
Jemez	4,000-acre-foot Sediment Pool	Irrigation demand	Does not affect the ability to pass water through Jemez to meet MRGCD irrigation demands.	X	
		Flooding	Does not affect overbank flooding	X	
		Flooding	Does not affect low flow velocity	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flood control	Level of protection for flood control remains the same. Storage takes place within sediment pool storage space.	X	
		Pool elevations	Higher pool elevations as a result of the storage of native water. Native water would be exchanged with SJC water being released from Abiquiu.	X	
		Reservoir levels	Could have more fluctuation in reservoir levels during spring runoff and irrigation season.	X	
		Peak discharge	Should not impact peak discharge on mainstem below Cochiti.	X	
		Narrowing of River Channel	Not likely to affect narrowing of river channel due to long-term reduction in channel forming discharge.	X	
		Maintenance flows	Should not impact maintenance flows required by riparian ecosystem.	X	
		Sediment transport	Slight reduction in the ability to transport sediment through the system when storage is taking place.	X	
		Spawning flows	There should be no reduction in spawning flows. Storage would only take place when all needs are met.	X	
		Spawning flows	Could have the ability to manufacture a spawning flow with SJC water stored.	X	
		Rio Grande Compact	Likely impact to Rio Grande Compact obligations if water is stored for other purposes other then compact deliveries.		
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation. Water could be released during summer or winter months for compact deliveries.		
		Floodplain encroachment	Should have no impact on encroachment (houses) in the floodplain in the middle valley.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Winter flows	Lower winter flows from November to March below Jemez if storage of native water is taking place.	X	
		Bank erosion	Reduces bank sloughing because of lower releases while conservation storage is taking place.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
Jemez	24,000-acre-foot Sediment Pool	Irrigation demand	Does not affect the ability to pass water through Jemez to meet MRGCD irrigation demands.	X	
		Flooding	Does not affect overbank flooding	X	
		Flooding	Does not affect low flow velocity	X	
		Flood control	Level of protection for flood control remains the same. Storage takes place within existing sediment pool space.	X	
		Pool elevations	Higher pool elevations as a result of the storage of native water. Native water would be exchanged with SJC water being released from Abiquiu.	X	
		Reservoir levels	Could have more fluctuation in reservoir levels during spring runoff and irrigation season.	X	
		Peak discharge	Should not impact peak discharge on mainstem below Cochiti.	X	
		Narrowing of channel	Likely to affect narrowing of river channel due to long-term reduction in channel forming discharge if done every year.		
		Maintenance flows	Reduction in maintenance flows required by riparian ecosystem.		
		Sediment transport	Reduction in the ability to transport sediment through the system when storage is taking place.		
		Spawning flows	There should be no reduction in spawning flows. Storage would only take place when all needs are met.	X	
		Spawning flows	Could have the ability to manufacture a spawning flow with SJC water.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Rio Grande Compact	Likely impact to Rio Grande Compact obligations if water is stored for other purposes other then compact deliveries. Mitigation may be required		
		Rio Grande Compact	Changes in evaporation and transportation losses potentially favorable to Compact, depending on storage/release use/timing. If not, would require mitigation.		
		Narrowing of channel	Should have no impact on encroachment (houses) in the floodplain in the middle valley.	X	
		Winter flows	Lower winter flows from November to March below Jemez if storage of native water is taking place.	X	
		Pool elevations	More stable pools during the recreation season if water is released from November to March.	X	
		Bank erosion	Reduces bank sloughing because of lower releases while storage is taking place.	X	
		Low flow conveyance channel	Should not impact low flow conveyance channel operation.	X	
LFCC	No LFCC Diversions	Rio Grande Compact	Reduction in NM's ability to meet to Rio Grande Compact obligations. Greater transmission losses occur when all flow is left in the Rio Grande floodway. Mitigation required.		
		Irrigation demand	Negligible impact on ability of MRGCD to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	
		Irrigation demand	Negligible impact on ability of Bosque del Apache NWR to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		ESA Recovery	Under some conditions, may support ESA recovery efforts for Rio Grande Silvery Minnow and Southwest Willow Flycatcher by providing greater flow in floodway.	X	
		Spawning flows	Supports creating spawning surge flows for Silvery Minnow	X	
		Flooding	Supports overbank flooding and riparian recovery efforts.	X	
		Sediment transport	Supports transport of sediment below San Acacia through higher flood flows, and may decrease tendency for aggradation.	X	
		Flooding	May impair ability to control flooding below San Acacia.		
		Water delivery	No impact on SJC water deliveries.	X	
LFCC	LFCC Diversions Leave 400 cfs Past San Acacia	Rio Grande Compact	Possible impact to Rio Grande Compact obligations. Greater transmission losses occur when all flow is left in the Rio Grande floodway.		
		Irrigation demand	Negligible impact on ability of MRGCD to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	
		Irrigation demand	Negligible impact on ability of Bosque del Apache NWR to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	
		ESA Recovery	Supports ESA recovery efforts for Rio Grande Silvery Minnow and Southwest Willow Flycatcher by providing greater flow in floodway.	X	
		Spawning flows	May not provide sufficient flow for Silvery Minnow spawning surge. Will meet purpose and need if occasional flood flows are allowed to pass > 400 cfs.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flooding	Little overbank flooding will occur if flows are always restricted to ≤ 400 cfs. Limits riparian recovery efforts. Will meet purpose and need if occasional flood flows are allowed to pass > 400 cfs.	X	
		Sediment transport	Restricts transport of sediment below San Acacia if flows are always restricted to ≤ 400 cfs, and may increase tendency for aggradation. Will meet purpose and need if occasional flood flows are allowed to pass > 400 cfs.	X	
		Flooding	Supports ability to control flooding below San Acacia.	X	
		Water delivery	No impact on SJC water deliveries.	X	
LFCC	LFCC Diversions Leave 150 cfs Past San Acacia	Rio Grande Compact	Possible impact to Rio Grande Compact obligations. Greater transmission losses occur when all flow is left in the Rio Grande floodway.		
		Irrigation demand	Negligible impact on ability of MRGCD to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	
		Irrigation demand	Negligible impact on ability of Bosque del Apache NWR to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	
		ESA Recovery	Supports ESA recovery efforts for Rio Grande Silvery Minnow and Southwest Willow Flycatcher by providing greater flow in floodway.	X	
		Spawning flows	Does not provide sufficient flow for Silvery Minnow spawning surge. Will meet purpose and need if occasional flood flows are allowed to pass much greater than 150 cfs.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flooding	No overbank flooding will occur if flows are always restricted to ≤ 150 cfs. Limits riparian recovery efforts. Will meet purpose and need if occasional flood flows are allowed to pass.	X	
		Sediment transport	Restricts transport of sediment below San Acacia if flows are always restricted to ≤ 150 cfs, and may increase tendency for aggradation. Will meet purpose and need if occasional flood flows are allowed to pass.	X	
		Flooding	Supports ability to control flooding below San Acacia.	X	
		Water delivery	No impact on SJC water deliveries.	X	
LFCC	LFCC Diversions Leave 50 cfs Past San Acacia	Rio Grande Compact	Possible impact to Rio Grande Compact obligations. Greater transmission losses occur when all flow is left in the Rio Grande floodway.		
		Irrigation demand	Negligible impact on ability of MRGCD to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	
		Irrigation demand	Negligible impact on ability of Bosque del Apache NWR to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	
		ESA Recovery	Probably insufficient flow to support ESA recovery efforts for Rio Grande Silvery Minnow and Southwest Willow Flycatcher; unless conducted in combination with LFCC diversions to floodway.		
		Spawning flows	Does not provide sufficient flow for Silvery Minnow spawning surge. May meet purpose and need if occasional flood flows are allowed to pass much greater than 50 cfs.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flooding	No overbank flooding will occur if flows are always restricted to ≤ 50 cfs. Limits riparian recovery efforts. May meet purpose and need if occasional flood flows are allowed to pass.	X	
		Sediment transport	Restricts transport of sediment below San Acacia if flows are always restricted to ≤ 50 cfs, and may increase tendency for aggradation. May meet purpose and need if occasional flood flows are allowed to pass.	X	
		Flooding	Supports ability to control flooding below San Acacia.	X	
		Water delivery	No impact on SJC water deliveries.	X	
LFCC	LFCC Diversions Leave Sufficient Water to get 50 cfs Past San Marcial	Rio Grande Compact	Possible impact to Rio Grande Compact obligations. Greater transmission losses occur when all flow is left in the Rio Grande floodway.		
		Irrigation delivery	Negligible impact on ability of MRGCD to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	
		Irrigation delivery	Negligible impact on ability of Bosque del Apache NWR to divert from LFCC. LFCC typically gains sufficient flow for limited diversions through irrigation drainage and groundwater inflow.	X	
		ESA Recovery	Supports ESA recovery efforts for Rio Grande Silvery Minnow and Southwest Willow Flycatcher by providing greater flow in floodway.	X	
		Spawning flows	Does not provide sufficient flow for Silvery Minnow spawning surge. May meet purpose and need if occasional flood flows are allowed to pass.	X	

Facility	Action	Water Operations Attribute	Rationale	No obvious inconsistency with Needs & Purposes	Fatal Flaw
		Flooding	No overbank flooding will occur if flows are always restricted to ≤ 50 cfs at San Marcial. Limits riparian recovery efforts. May meet purpose and need if occasional flood flows are allowed to pass.	X	
		Sediment transport	Restricts transport of sediment below San Acacia if flows are always restricted to ≤ 50 cfs at San Marcial, and may increase tendency for aggradation. May meet purpose and need if occasional flood flows are allowed to pass.	X	
		Flooding	Supports ability to control flooding below San Acacia.	X	
		Water delivery	No impact on SJC water deliveries.	X	

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9.0 ATTACHMENT B COMMUNICATION & COORDINATION PROTOCOL

Communication & Coordination Protocol

Coordination Protocol

The following is the general inter-agency process, which is part of the annual water operations coordination process.

Water managers meet in February, March and April, to discuss water operations issues, needs, and objectives for the upcoming year. The meeting in February provides a general overview of project operations based on the projected snowmelt runoff. The Bureau of Reclamation holds the meeting and invites all the stakeholders in the Basin. Presentations are made on water supply and endangered species operations.

Water managers meet or exchange information after the April snowmelt runoff forecast is available. Reclamation and the Corps develop an Annual Operating Plan (AOP) with input from the Irrigation Districts. Reclamation and the Corps hold open forum public meetings in April and May to discuss the AOP. After the AOP is developed public meetings are held in Albuquerque, Las Cruces, Socorro, Truth or Consequences, New Mexico, and El Paso, Texas. The Corps also holds open forum meetings at Abiquiu and Cochiti to discuss the current year water supply. The AOP is also placed on Reclamation web page. The Corps also uses the AOP to project flood control operations and expected maximum releases below the dams. The Corps has a 1-800-number at Abiquiu Reservoir project office, which provides a forecasted flow for the next day. The forecast is updated by 10:00 am each morning.

After runoff, through the end of the irrigation season, frequent coordination becomes more critical. Weekly, and often daily, communications occur between Reclamation, the Corps, the USFWS, Middle Rio Grande Conservancy District (MRGCD), City of Albuquerque, and the State of New Mexico during the irrigation season. This process involves meetings, conference calls, and information exchange. An important component of the daily conference calls is to agree on the operational adjustments necessary to meet the suite of water management objectives, such as the management of available supplemental water and irrigation demand in the Middle Valley based on real-time data.

The Corps and Reclamation are always conferring on the type of water (San Juan-Chama/Native) being released from reservoirs upstream of Cochiti Lake. The Corps stores San Juan-Chama (SJC) water that is destined for Abiquiu Reservoir and Cochiti Lake and bypasses SJC water that is payback to the river as a result of groundwater pumping, or SJC water being moved to Elephant Butte Reservoir. Reclamation coordinates SJC water releases with the Corps on a daily basis when needed. The New Mexico Interstate Stream Commission provides a letter to Reclamation with details on the amount of water owed to the river and the name of the contractors that need to payback the river for over pumping. Movement of SJC water to Elephant Butte would be at the request of the contractors.

The following is an outline to improve inter-agency coordination process within the agencies and also with the public.

a. Water managers meet in February, March, and April, to discuss water operations issues, needs, and objectives for the upcoming year. The meeting provides a general overview of project operations based on the projected snowmelt runoff. Post meeting notes and presentations on the web for the public access.

b. Provide snowmelt runoff projections from January to May and post on the web. Provide written descriptions of changes that occur from the existing projections.

c. Notify tribes along the river on reservoir operations.

d. Provide a weekly update on reservoir operations on the web throughout the year.

e. Provide a 1-800 number where the public can call in for the weekly update on reservoir operations.

f. Post on the web a description on how the supplemental water program works and the current plan for the year

The above discussion presents some key points in the coordination process. Representation from Reclamation, the Corps, MRGCD, ISC, F&WS, IBWC, city of Albuquerque and BIA form the core of agencies involved with day-to-day management of the Rio Grande. Regular conference calls could be the primary means of information exchange and meetings would be scheduled as necessary. While particular water operations plans may not pertain to all agencies everyone could benefit from the exchange of information.

Protocol For Operation Of Upstream Projects For Flood Control Below Elephant Butte And Caballo Reservoirs

The following is the general description of the coordination process that would occur if the Corps projects upstream of Elephant Butte were operating to provide flood protection below Caballo Dam.

The Corps will provide flood protection for areas below Elephant Butte and Caballo Reservoir if their conservation pools are full and releasing up to channel capacity. The USIBWC would be the agency determining what the channel capacity is below Caballo. However the Corps first priority would be the protection of its structures and flood protection for areas above Elephant Butte Reservoir and below the Corps structures.

Water managers meet in February, prior to the onset of the irrigation season, to discuss water operations issues, needs, and objectives for the upcoming year. The meeting in February provides a general overview of project operations based on the projected snowmelt runoff. The Bureau of Reclamation in Albuquerque holds the meeting and invites all the stakeholders in the Basin. Presentations are made on water supply and endangered species operations. Water managers meet or exchange information after the April 1, snowmelt runoff forecast is available. The Corps, Reclamation and United States Section of International Boundary and Water Commission (USIBWC) would start to discuss the operation of Elephant Butte and Caballo Reservoir flood control after the April 1 runoff projections. The Corps release rate from Cochiti and Jemez would be set to maintain a constant 5,000 cfs release below Elephant Butte Reservoir if operating for flood control below Caballo Dam. The key to successful flood control operation is weekly or daily communications as needed between the Corps, Reclamation, USIBWC and the New Mexico Interstate Stream Commission. The Corps would coordinate with the Rio Grande Compact Commissioners on the operation of the Corps reservoirs for flood protection below Caballo Dam. This process involves meetings, conference calls, and information exchange between the agencies.

The following scenario is one that did occur in 1987 and is provided as an example on how the Corps projects would be used to provide flood protection below Caballo Reservoir.

In January 1987 early season projections were for 110 to 130 percent of normal in the Colorado portion of the basin and 95 to 135 percent of normal in New Mexico. Fall precipitation was above normal over most of the basin. For the month of November, precipitation totals were 2 to 3 times normal monthly totals. Precipitation totals for the month of January were above normal over much of the basin. Strong storm systems during the early and middle portion of the month produced relatively heavy amounts of precipitation resulting in monthly totals 2 to 4 times the long-term January normals over all of the San Luis Valley in Colorado and the northern Rio Grande valley in New Mexico. The March 1 snowmelt runoff forecast was for above average runoff. The Sangre de Cristos tributaries were expected to produce runoff 120 to 160 percent of average. Precipitation during the month of February was above average over most of the basin with the majority of the reporting stations receiving 150 to 200 percent of average. Stream flows based on April forecasts were expected to range from 140 to 167 percent average along the main stem and from 92 to 175 percent of average along the tributaries. March precipitation totals were variable in the basin. Above normal amounts 150 to 250 percent of average were recorded in the upper reaches of the basin above Del Norte in Colorado. Farther south, amounts decreased to around 50 to 70 percent in the Colorado/New Mexico border region and only 5 to 20 percent in the Albuquerque and Santa Fe area. The May 1 snowpack showed significant depletion at middle and lower elevations since early April, reflecting above normal temperatures for the last month. In Colorado the forecast was for 120 percent of average. In New Mexico forecasts ranged from 200 to 260 percent on the mainstem of the Rio Grande and 125 to 175 percent of average along the tributaries. A large percentage of the snowpack melted in April producing above normal runoff and streamflow for the month of April.

The weather system that moved in to produce the 1987 snowmelt runoff in the Rio Grande Basin of about 200 percent of normal as recorded at the Otowi gage was a remarkably persistent split-flow circulation pattern where polar-front jet stream remained in Canada north of its normal position and an active subtropical jet stream, which crossed the southern United States, led to above normal flows in the central one-third of the U.S. High volume discharges in the Rio Grande resulted from fall, winter, and spring precipitation throughout the entire Rio Grande Basin of Colorado and northern New Mexico.

Abiquiu Reservoir began storing snowmelt runoff on 12 April and reached a record pool elevation of 6,262.06 feet, NGVD (402,258 acre-feet) on 22 June. The maximum release was 1,826 cfs. Cochiti Lake began storing water on February 27 and reached a maximum pool at elevation 5434.50 feet (396,167 acre-feet). The peak discharge at Albuquerque occurred on 24 July and reached approximately 7,840 cfs. Jemez Canyon Reservoir also reached a record pool elevation in 1987 with flood control storage starting on April 13 and resulting in a maximum elevation of 5,220.30 feet (72,524 ac-ft) on June 2. The magnitude of storage was attributed to Elephant Butte and Caballo Reservoirs being full. Elephant Butte reached a maximum storage of 2,095,600 ac-ft on March 27. The maximum release from Elephant Butte was 4, 830 cfs on June 3. Caballo Reservoir reached a maximum storage of 262, 600 ac-ft on June 24. The maximum release from Caballo was 4,646 cfs on July 11.

The Rio Grande below El Paso, Texas had not experienced sustained flood flows since the early 1940's. Therefore, a considerable amount of sediment aggradation had occurred, which severely reduced channel capacities through Fort Quitman. This resulted in numerous levee breaches on the Mexican side of the river and high water tables in the agricultural areas on the United States side. The Corps, Reclamation and USIBWC were in frequent contact on the channel capacity below Caballo. Channel capacity issues extended all the way to the Fort Quitman area. The lack of channel capacity in these areas hindered the release of floodwater from Abiquiu, Cochiti and Jemez Canyon Reservoirs.

10.0 ATTACHMENT C NO-ACTION ALTERNATIVE

Upper Rio Grande Basin Water Operations Review

No Action Alternative

Goals	Maintain existing operational conditions: r) Provide flood and sediment control; s) Store and deliver water for agricultural, domestic, municipal, and industrial uses and for recreational and fish and wildlife benefits. t) Meet compact obligations and limit losses; u) Time scheduled deliveries, as approved by willing water owners, to provide incidental water quality, recreation, fish and wildlife and other environmental benefits.
Closed Basin Project Owned & operated by Reclamation Oversight provided by a three member Operating Committee consisting of one representative from the Colorado Water Conservation Board (CWCB), one from the Rio Grande Water Conservation District, and a member appointed by the Secretary of Interior (Reclamation). Purpose: First priority: assist Colorado in meeting annual deliveries under the Rio Grande Compact Second priority: maintain the Alamosa National Wildlife Refuge and the Blanca Wildlife Habitat Area, and stabilize San Luis Lake Third priority: allow Colorado to apply to the reduction and elimination of any accumulated deficit in the deliveries as determined by the Rio Grande Compact Commission. Fourth priority: provide irrigation supply and other beneficial uses in Colorado (has never occurred	Operated, subject to production and water quality constraints, for: ***a) Authorized production of up to 600,000 a-f from groundwater wells in any consecutive ten-year period specifically to assist the State of Colorado in meeting annual Rio Grande Compact deliveries.*** ***b) Up to 5,300 a-f/y for wildlife mitigation*** ***Constraints:*** ***a) Average annual production is currently limited to approximately 25,000 a-f/y due to well degradation.*** ***b) Deliveries to river require compliance with Clean Water Act standards.*** ***c) Pumping levels are also subject to drawdown constraint.*** Operating Committee composed of Colorado Water Conservation Board, Rio Grande Water Conservation District and Reclamation to provide oversight to ensure project is operated in accordance with authorizing legislation. Make recommendations on project operation.

Upper Rio Grande Basin
Water Operations Review

No Action Alternative	
Platoro Dam Only Flood Control within the authority of this review Owned by Bureau of Reclamation (Reclamation) Operated by Conejos Water Conservancy District (CWCD) Reclamation has safety of dams authority when flood control pool is exceeded. Purpose: Conservation storage (irrigation) and flood control Corps of Engineers (COE) has flood control authority	Operated for flood control with maximum releases up to channel capacity of 2,500 cfs at Conejos River at Mogote gage and 1,600 cfs at Conejos River at La Sauces gage. COE monitors joint-use pool (flood & conservation space) if flood space is needed, water in the conservation space is released to make room for flood inflows. Operated to maintain a 3,000 a-f permanent pool for recreation and fish and wildlife. Operated to preserve fish & wildlife habitat below Platoro Reservoir; CWCD maintains a 7 cfs release during the months of October through April, and bypass 40 cfs or natural inflow whichever is less, during the months of May through September

Upper Rio Grande Basin Water Operations Review

No Action Alternative

HERON RESERVOIR

Owned & operated by Reclamation

Purpose:
Storage and delivery of San Juan Chama Project water for irrigation and municipal, domestic and industrial uses, and associated benefits to recreation, fish and wildlife

Maximize storage San Juan-Chama Project (SJC) water up to reservoir capacity of 400,000 a-f to provide reliable supply to meet contractor demands. Water is released at the request of the contractors for downstream beneficial use in New Mexico up to contracted amount.

Limitations of San Juan Chama Project:

a) Water available for release to SJC contractors is based on “Firm Yield” of 96,200 a-f per year.

b) Transbasin diversions limited to 270,000 a-f in any one year and to 1,350,000 a-f in any 10 years.

c) Not authorized for storage of native Rio Grande water. All such native inflow is released on a monthly basis.

d) No hydropower allowed at Heron Reservoir (Colorado River Storage Project PL 84-485, 4/11/56).

Carryover storage of unused individual contractor water not permitted except by use of waivers. A “waiver “ is a temporary of requirement for contractors to take delivery of a current year allocation before December 31 of the same year.

By agreement with SJC contractors, releases are timed to maintain winter flows below El Vado for fish and wildlife benefits in accordance with instream flow study recommendations, provided in the BLM Management Plan[1] for compliance with the wild and Scenic Rivers Act, and to provide higher weekend flows for whitewater rafting between El Vado and Abiquiu during a 6-8 week period in the summer.

[1]Rio Chama Instream Flow Assessment, Denver, CO, U.S. Department of the Interior, Bureau of Land Management, 1992.

Upper Rio Grande Basin Water Operations Review

No Action Alternative	
El Vado Reservoir (Not within authority of this review — all alternatives reflect no action) Owned by MRGCD (Outlet, spillway - Reclamation) Operated by Reclamation under contract with MRGCD Power generation facilities owned & operated by Los Alamos County Purpose: Water storage for irrigation Provides incidental recreation, flood and sediment-control, and run of river power generation	Store and release native water for MRGCD subject to state water law and Rio Grande Compact restrictions. Maximum storage about 180,000 a-f. Bypass native water inflow up to 100 cfs or actual inflow if less for Rio Chama diverters, adjudicated diversion right is satisfied at 100 cfs. Store and release native water for prior and paramount uses as needed by Pueblos. Store SJC water for MRGCD and other contractors as approved by the MRGCD on yearly basis. SJC water released from Heron for downstream use are passed through. Make voluntary release exchanges (borrow/payback between MRGCD storage in El Vado and City of Albuquerque storage in Abiquiu) to support irrigation, municipal and industrial uses; releases may be timed for recreation and/or environmental purposes. Safe channel capacity is 4,500 cfs below El Vado Dam. Generate power through "run of the river" releases, with turbines operational between 250 cfs to 900 cfs.

Upper Rio Grande Basin
Water Operations Review

No Action Alternative	
Abiquiu Reservoir Owned & operated by COE Power generation facilities owned & operated by Los Alamos County Land acquired in fee was 2860.41 acres (elevation 6215.0 ft). Land acquired in flood easement contains 6,133 acres (elevation 6293.5 ft). Purpose: Flood control Sediment control SJC water supply storage, authorized to store native water Incidental recreation Run of river power generation	Operates for flood control with maximum releases up to channel capacity of 1,800 cfs below Abiquiu, 3,000 cfs at Chamita, 10,000 cfs at Otowi; limit on rate of change in downstream stage of .25 to .50 feet per gate change at gage below Abiquiu Dam. Unless in flood control operations, all native water is bypassed at a rate that is below safe channel capacity. Store SJC water (released from Heron to contractors) for city of Albuquerque and other contractors up to elevation of 6220 ft; release on request. City of Albuquerque holds easements to store San Juan-Chama water up to elevation 6220.0 ft. Make voluntary release exchanges (borrow/payback between MRGCD storage in El Vado and City of Albuquerque storage in Abiquiu) to support irrigation, municipal and industrial uses; releases may be timed for recreation and/or environmental purposes. Strive to maintain minimum flows for fisheries, such as 70 cfs for trout from November to March. Operation subject to PL 86-645 restriction for Compact purposes: a) The COE is directed to hold (carry-over) floodwater in Abiquiu Reservoir or Cochiti Lake after July 1. When the natural flow at Otowi gage falls below 1,500 cfs, water must subsequently be released between November 1 and March 31. Generate power through "run of the river" releases. Note: Whenever flow falls below 150 CFS, turbines cannot generate power.

Upper Rio Grande Basin Water Operations Review

No Action Alternative	
Cochiti Reservoir Owned and operated by COE Flood easements acquired from US Forest Service (8,236 acres), Pueblo de Cochiti (4,069 acres), Atomic Energy Commission (345 acres), National Park Service (361 acres), University of New Mexico (540 acres), and private concerns (139 acres). Purpose: Flood and sediment control, fish and wildlife enhancement, recreation Operated to bypass native inflow	Operated for flood control: release inflows as quickly as possible without causing flooding (in conjunction with Abiquiu, Jemez Canyon and Galisteo Reservoirs such that flows do not to exceed 7,000 cfs at Albuquerque); and subject to change of stage not to exceed 0.5 foot each change at the downstream gage from Cochiti Dam. Permanent SJC recreation pool of 1,200 surface acres (volume approximately 50,000 a-f) is maintained. Evaporative losses from recreation pool are replaced with San Juan Chama water. Operation subject to PL 86-645 restriction for Compact purposes. a) The COE is directed to hold (carry-over) floodwater in Abiquiu or Cochiti Reservoir after July 1 when the natural flow at Otowi gage falls below 1,500 cfs, water must subsequently be released between November 1 and March 31. b) A provision in the law requires that 212,000 a-f of space is available for control of summer floods. If 212,000 a-f of space is not available releases from Cochiti can continue from July 1 through November 1 to evacuate flood water in the space needed.
Jemez Canyon Reservoir Owned and operated by COE Located on Pueblo of Santa Ana land Purpose: Flood and sediment control	Operated for flood control (max. 73,000 af): release inflows as quickly as possible without causing flooding (in conjunction with Abiquiu, Cochiti and Galisteo Reservoirs such that flows do not to exceed 7,000 cfs at Albuquerque). Operated as a dry reservoir for flood and sediment control. Limitation on rate of change in stage at the downstream gage of .25 to .50 feet per gate change for public safety.
Low Flow Conveyance Channel Owned by Reclamation Purpose: Convey lower flows of the Rio Grande, improve drainage, supplement irrigation water supply and assist New Mexico in making compact deliveries.	Diversions up to 2,000 cfs at San Acacia are possible when physical outfall conditions allow. Drainage flows in the Low Flow Conveyance Channel: a) Supply the majority of the water needs at Bosque del Apache National Wildlife Refuge. b) Supply MRGCD with irrigation water. c) In 2000 and 2001 drainage flows were pumped to the river during low flows to support endangered species habitat as per State Engineer granted emergency authorizations.

Upper Rio Grande Basin Water Operations Review

No Action Alternative

Elephant Butte Reservoir Only Flood Control within the authority of this review Owned & operated by Reclamation Power generation facilities owned by Reclamation Purpose: Water supply for irrigation and M&I use, recreation and flood control Secondary operation for hydroelectric power Provides incidental sediment control	Operation of the project retains all inflows in excess of downstream irrigation demand. Releases from Elephant Butte Dam during the irrigation season are to satisfy irrigation demand downstream of Caballo Dam, and maintain Caballo Reservoir's lake level per Court Order of 1996. Maintain a 50,000 a-f flood control space from April 1 to September 30 (summer months) and a 25,000 a-f flood space from October 1 to March 31 (winter months). Releases are controlled to the channel capacity of 5,000 cfs below the dam. Generation of hydroelectric power is a secondary purpose. Maximum powerplant release is 2,400 cfs. Rio Grande Convention of 1906 and 1933 Extension between Mexico and the United States obligates the delivery of 60,000 a-f of water to Mexico's Acequia Madre headworks annually unless extraordinary or serious accident occurred to the irrigation system in the United States. . Flood control releases are required when the reservoir level is within the flood control space. Flood control releases are coordinated with Caballo Reservoir, upstream COE projects, and International Boundary and Water Commission (IBWC). Releases cease at the end of the irrigation season, typically mid-October.

Upper Rio Grande Basin Water Operations Review

No Action Alternative

Caballo Reservoir

Only Flood Control within the authority of this review

Owned by Reclamation

Reclamation authorized to assume operations for the purpose of dam safety once the top of flood pool is exceeded.

Purpose:
- Water supply for irrigation and M&I use, and flood control
- Provides incidental sediment control and incidental fish & wildlife purposes.

Flood Control operations are directed by IBWC. Generally, USIBWC requires the 100,000 a-f flood pool will be completely evacuated as quickly and safely as possible from June 1st to October 31st.

Flood control releases are required when the reservoir level is within the flood control space. Releases are coordinated with Elephant Butte Reservoir, upstream COE projects and IBWC.

Operation of the project retains all inflows in excess of downstream irrigation demand and safe river channel capacity of 5,000 cfs or per IBWC direction. Target range is 2500-3500 cfs due to flood damage effects beginning to occur in Selden canyon above that flow.

IBWC, in coordination with Reclamation, controls the operation of the flood pool to control flow downstream of Caballo to less than 11,000 cfs at American Diversion Dam.

IBWC's Canalization Project levee system flood control capacity varies from 5,000 to about 22,000 cfs. Impacts downstream in some places start below 3,000 cfs.

Since Sept.17, 1991, Sec7 consultation, requires that Reclamation maintain a minimum pool of 25,000 a-f for fishery purposes and to support bald eagle habitat.

Since Court Order of 1996, reservoir is operated to maintain a storage level below 50,000 a-f from October 1st to January 31st to leave enough space for winter accretions. From February 1st to September 30th the reservoir is operated within a flexible storage between 50,000 and 80,000 a-f. This operation is to minimize the evaporation of both Elephant Butte and Caballo Reservoirs.

Rio Grande Convention of 1906 and 1933 Extension between Mexico and the United States obligates the delivery of 60,000 a-f of water to Mexico's Acequia Madre headworks annually unless extraordinary or serious accident occurred to the irrigation system in the United States.

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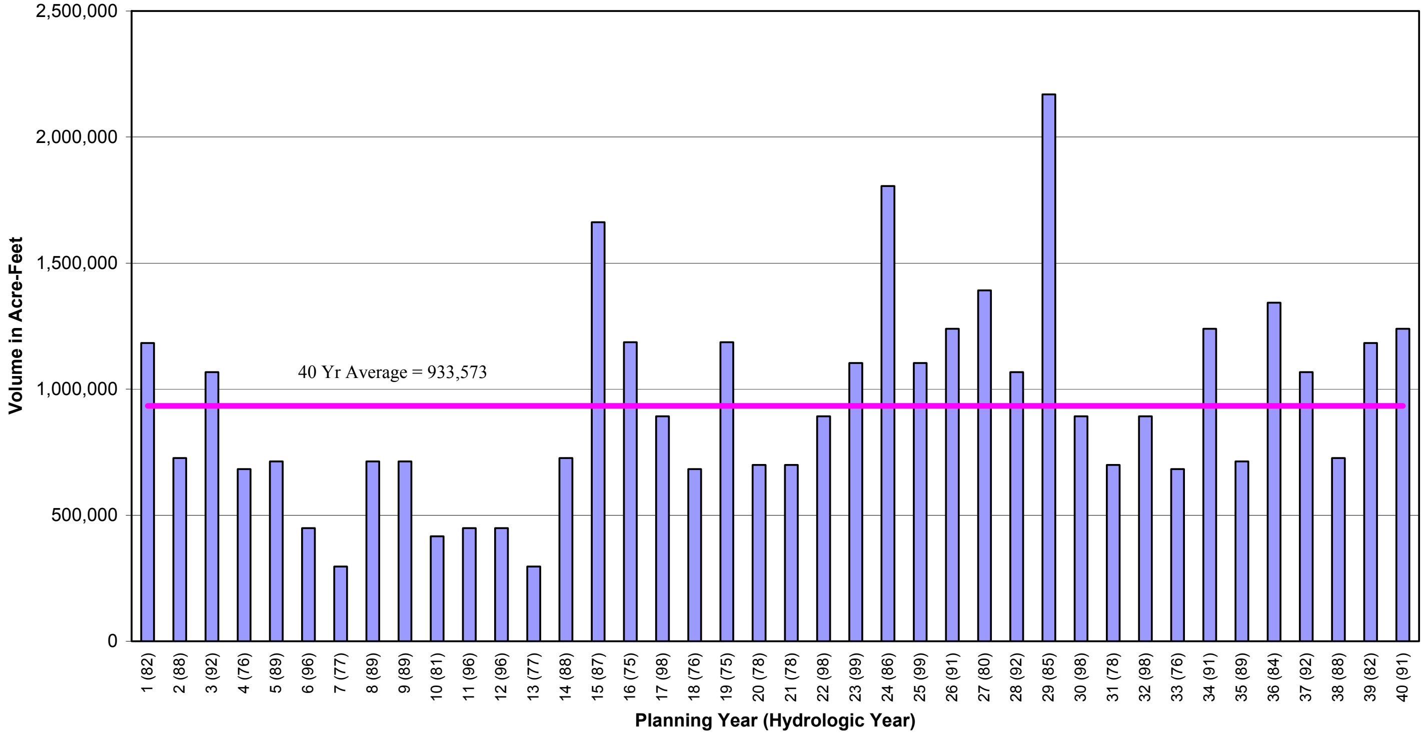
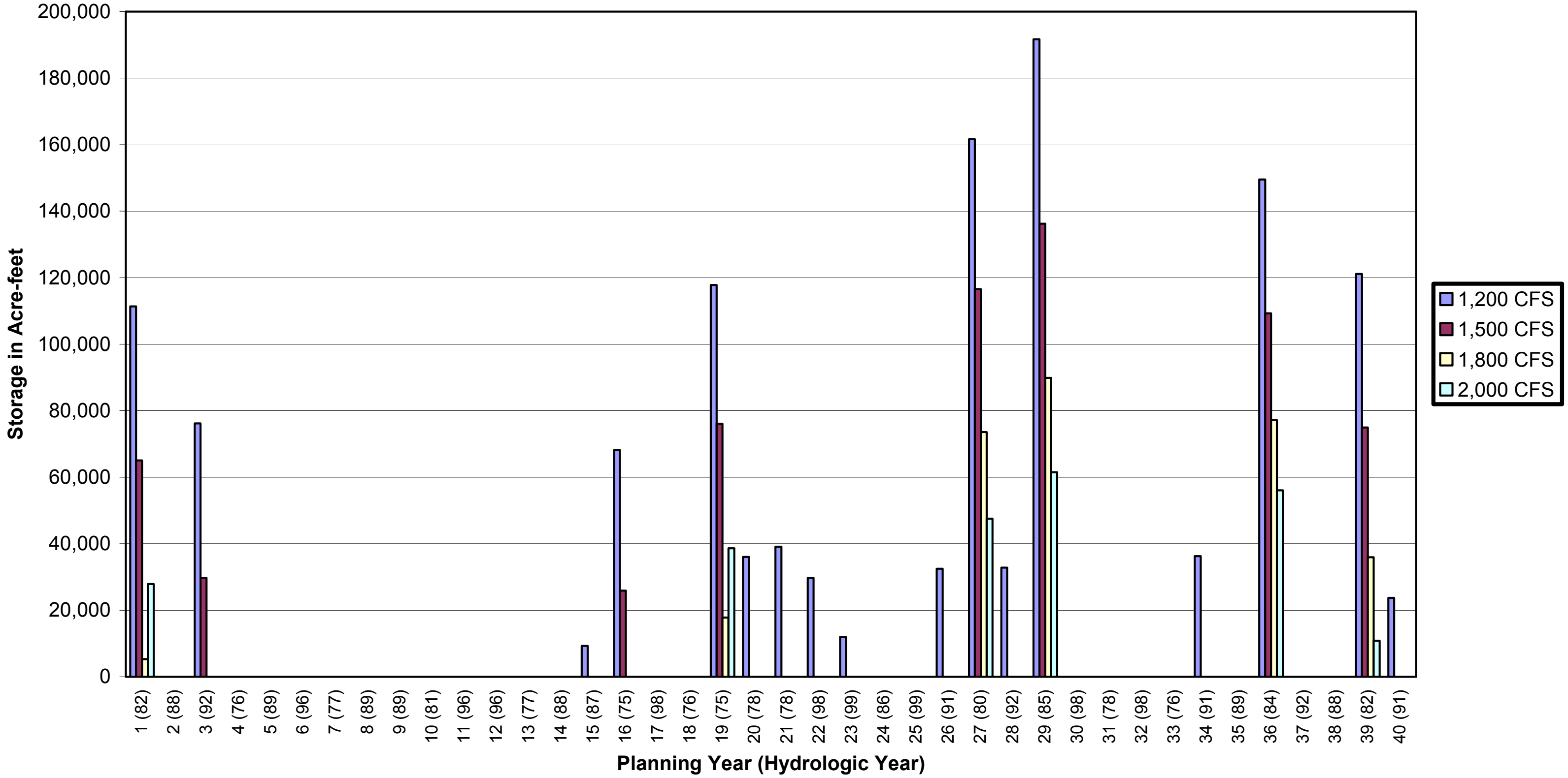
11.0 ATTACHMENT D FIGURES

Figure I.D-1: All Model Runs: 40 Year Otowi Flow Sequence



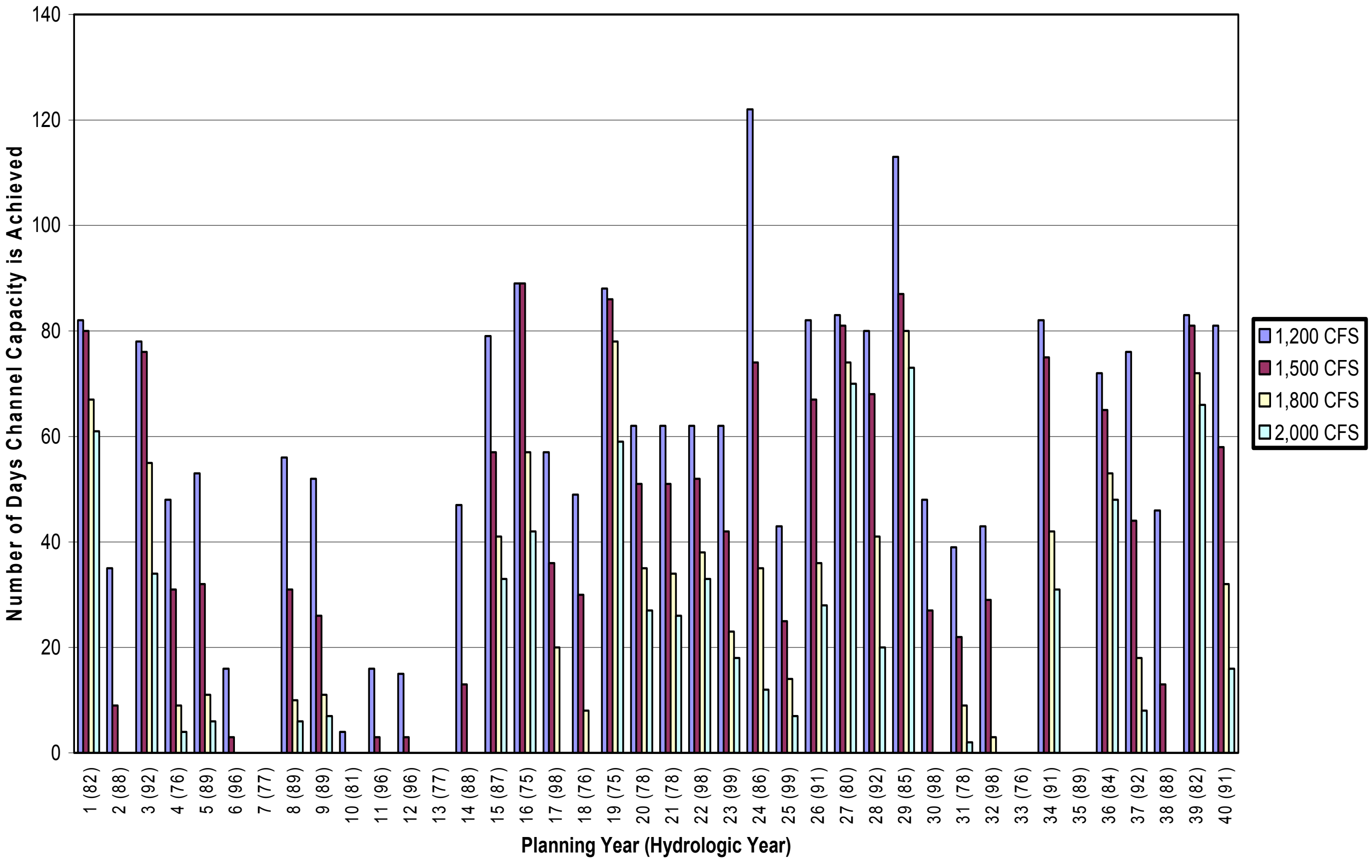
Hydrologic sequence for Otowi gage, developed by S.S. Papadopulos & Associates, Inc., described in a separate appendix.

Figure I.D-2: Sensitivity Analysis on Base Run of Various Abiquiu Channel Capacities



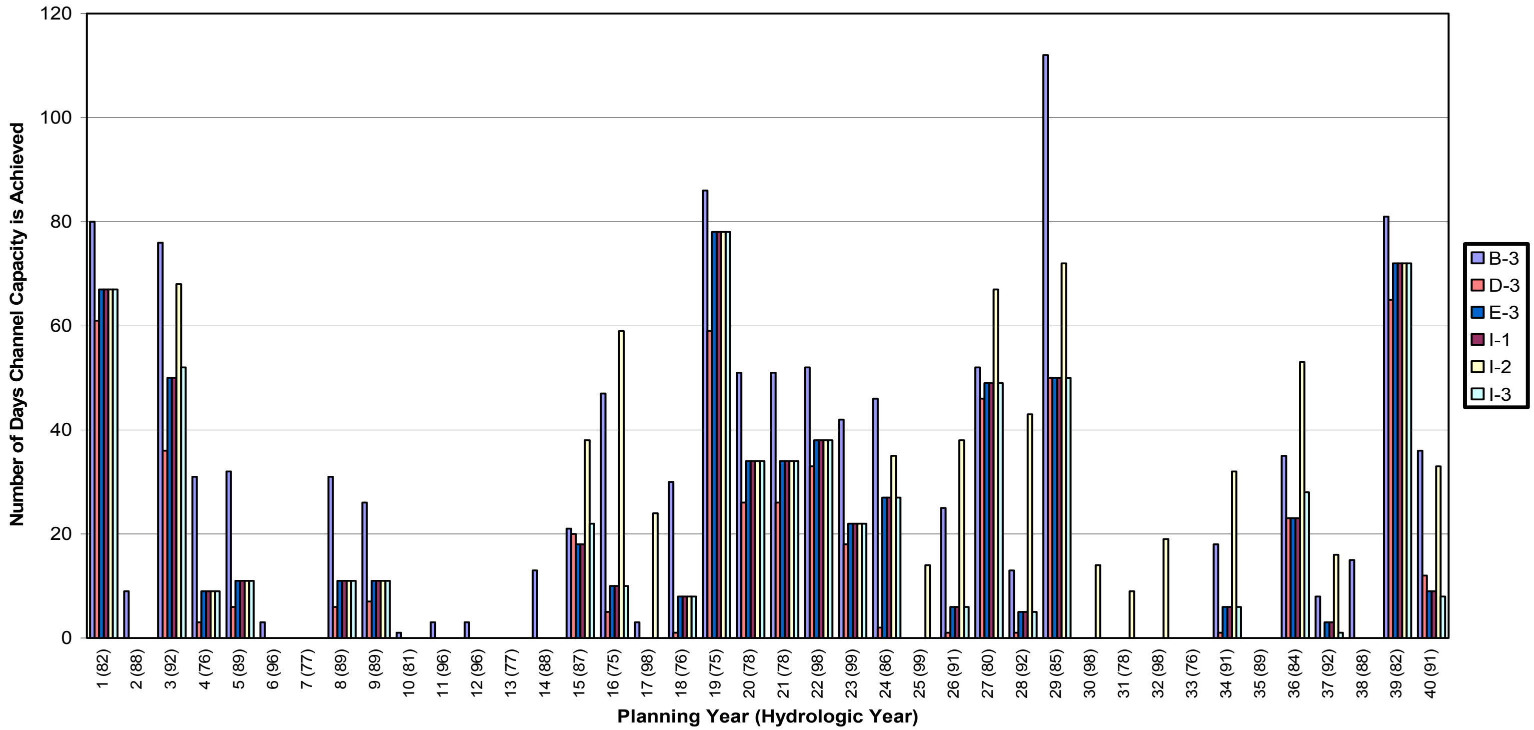
The graph above shows the results of lowering or increasing the channel capacity at Abiquiu Reservoir. The amount of carryover storage increases with a decrease in channel capacity and decreases with an increase in the channel capacity. Only channel capacity below Abiquiu Reservoir was varied in the Base Run Model.

Figure I.D-3: Number of Days in a Model Year that Abiquiu Channel Capacity Is Achieved



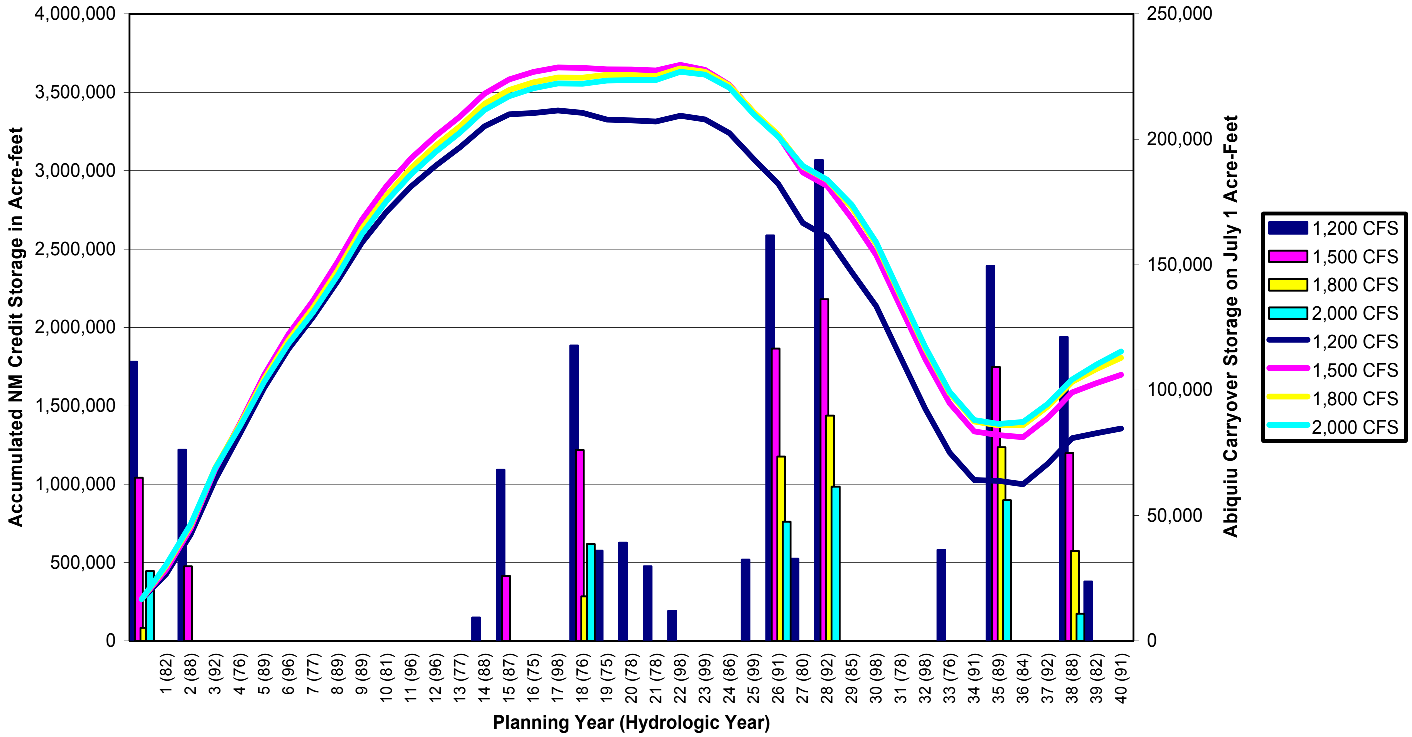
The graph above shows the results of lowering or increasing the channel capacity and the number of days that you would be at channel capacity. Lowering the channel capacity to 1200 cfs increases the number of days at flow and also increases the number of years that you would have carryover storage as shown in the previous graph.

Figure I.D-4: Number of Days Channel Capacity is Achieved at Abiquiu Per Action Alternative



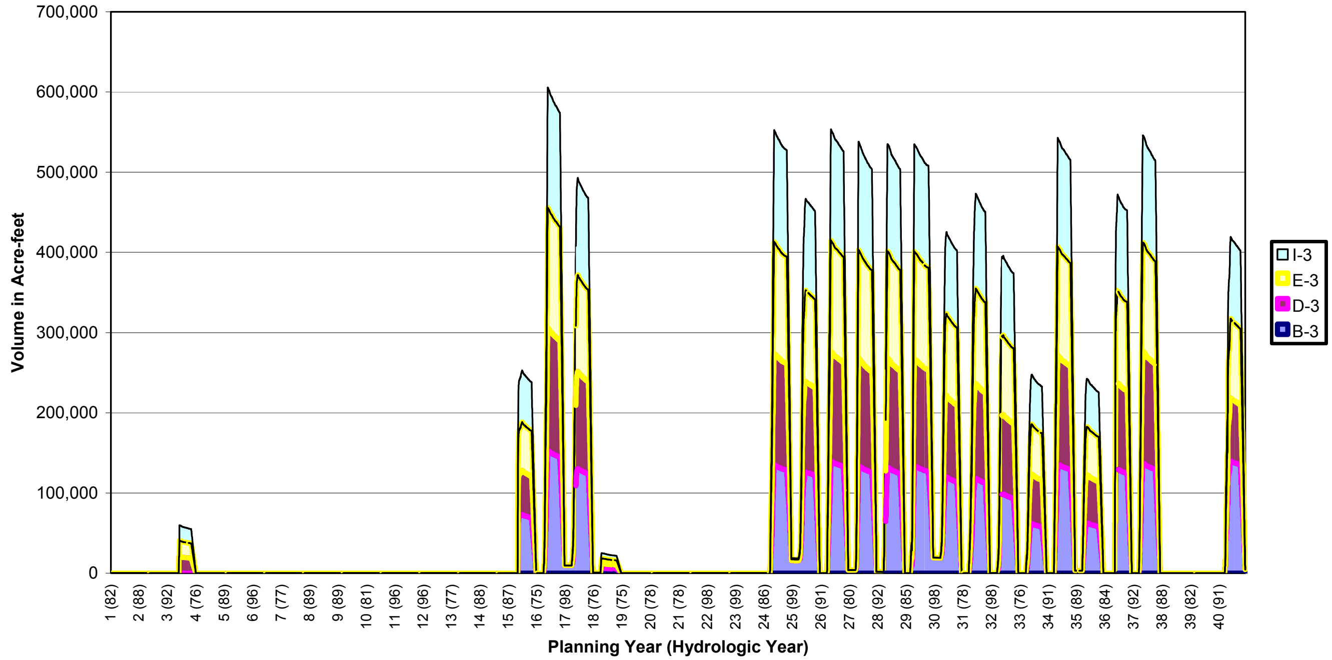
The graph shows the result of the different alternative model runs. Alternative B-3 in most years shows the highest number of days Abqiuiu Reservoir would be at channel capacity.

Figure I.D-5: Sensitivity Analysis on Base Run of Accumulated NM Credit Storage and Abiquiu Reservoir Carryover Storage Under Various Channel Capacities



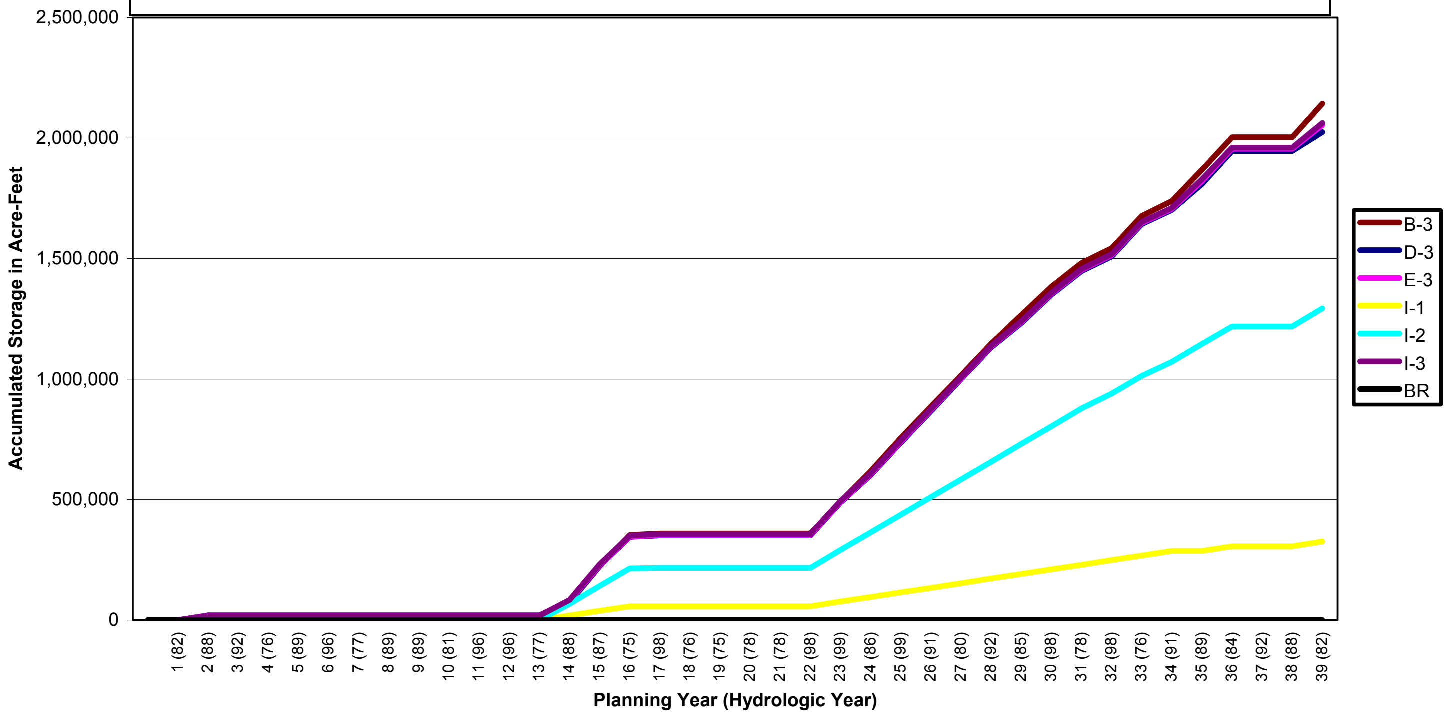
The results in the graph for accumulated NM credit should not be taken as actual values. The curves should be used only in relative terms to show trends and compare results between alternatives. The curves show that maintaining a higher channel capacity below Abiquiu Dam increases in compact deliveries.

Figure I.D-6: Abiquiu Conservation Storage Comparison Between Action Alternatives



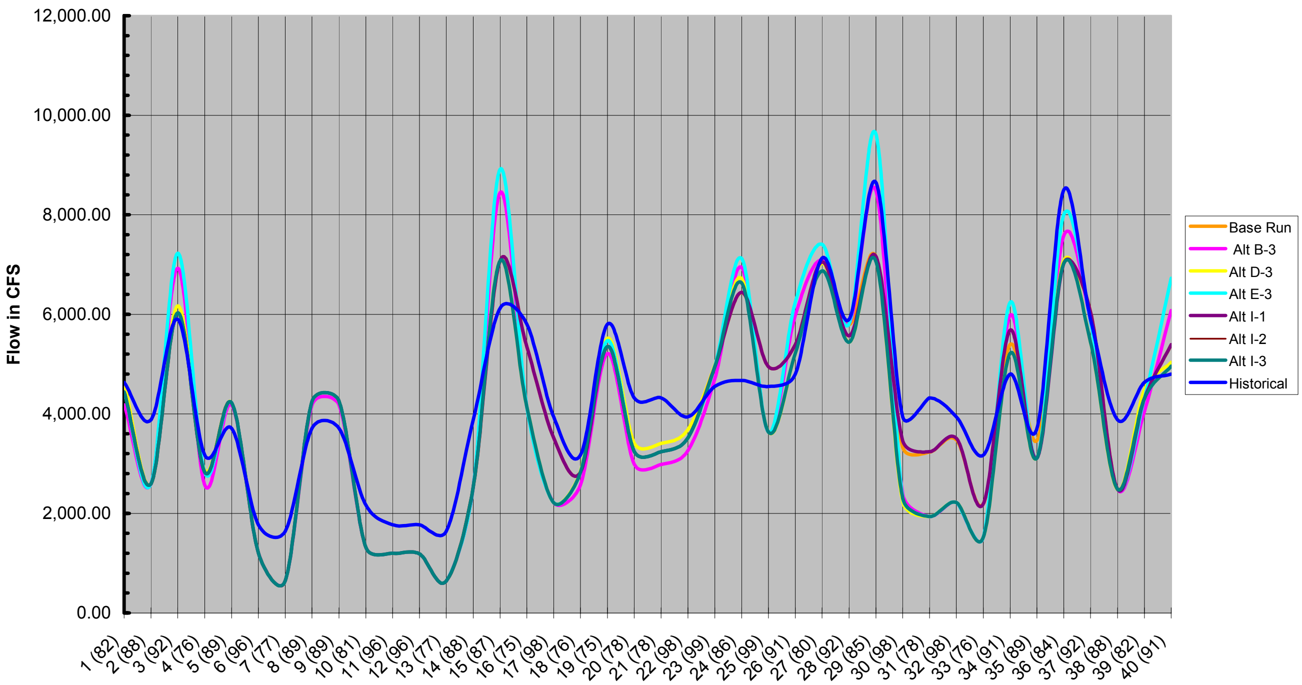
The results in the graph show the amount of conservation storage that could be captured under the different alternatives. The Base Run does not capture conservation therefore it is not shown. Alternative I-1 and I-2 conservation storage targets are below 180,000 acre-feet therefore were not plotted.

Figure I.D-7: Cumulative Annual Abiquiu Conservation Storage based on Annual July 1 Conservation Storage



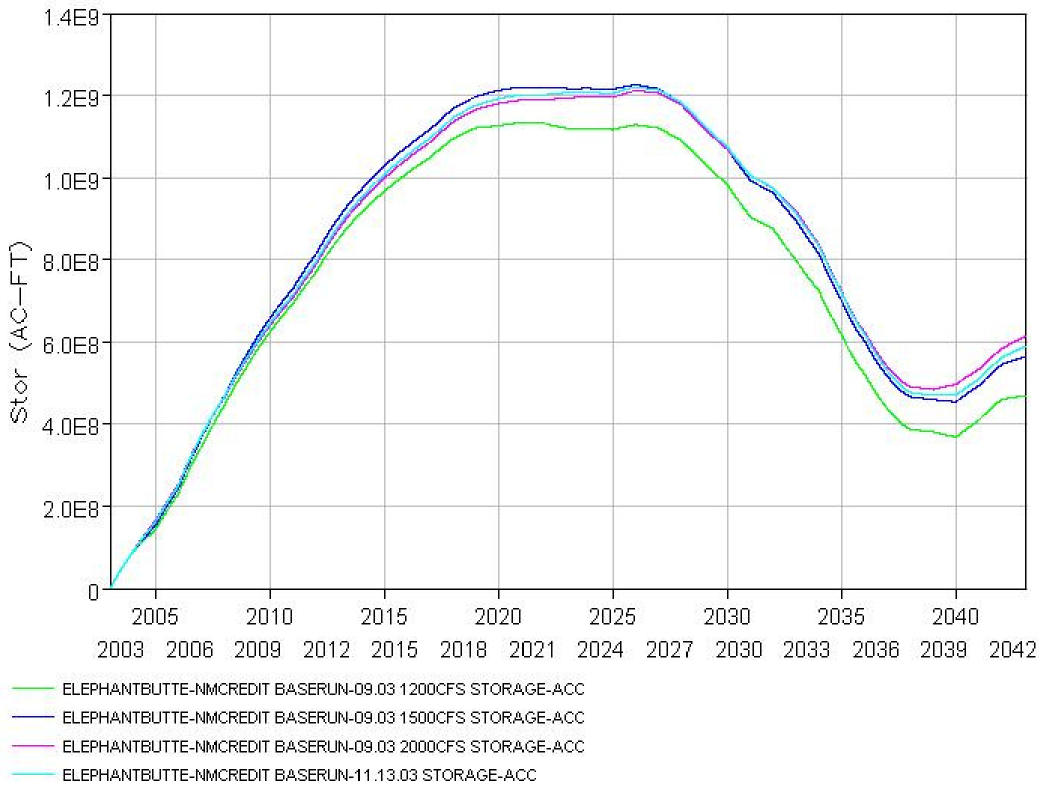
The graph shows the accumulated conservation storage over the 40-year model runs. Alternative B-3 has the most and I-1 with the least. The difference between alternatives B-3, D-3, E-3 and I-3 is relative small over the 40-years. The numbers shown on the graphs should not be used as actual numbers and used only in relative terms to show trends and compare results between alternatives.

Figure I.D-8: Summary of Peak Flows at Albuquerque



The graph above shows peak flows for all the alternatives, base run and the historical flow. The historical flow is presented only as a comparison. Starting conditions were different for the historical flows. Alternative E-3 provides the higher peak flows.

Figure I.D-9: Sensitivity Analysis on the Base Run to Evaluate NM Credit Storage with Various Rates of Release



The graph above shows the accumulated NM credit storage using the Base Run with a 1200, 1500, 2000 cfs release and allowing storage up to 75,000 acre-feet in the conservation pool at Abiquiu Reservoir. The Base Run with the 1800 cfs channel capacity is not storing conservation water. The graph is for comparison purposes only and values should not be taken as actual. The graph indicates a trend over the 40-years.

Figure I.D-10: Abiquiu Average Annual Storage (Model Year 1-40)

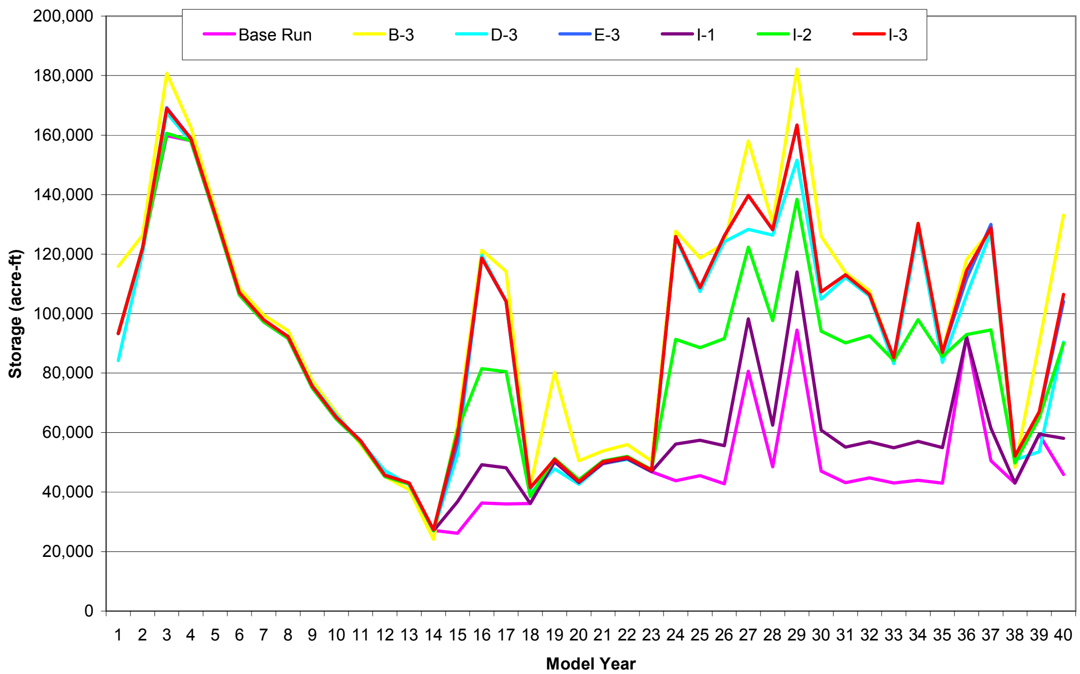


Figure I.D-11: Cochiti Average Annual Storage (Model Year 1-40)

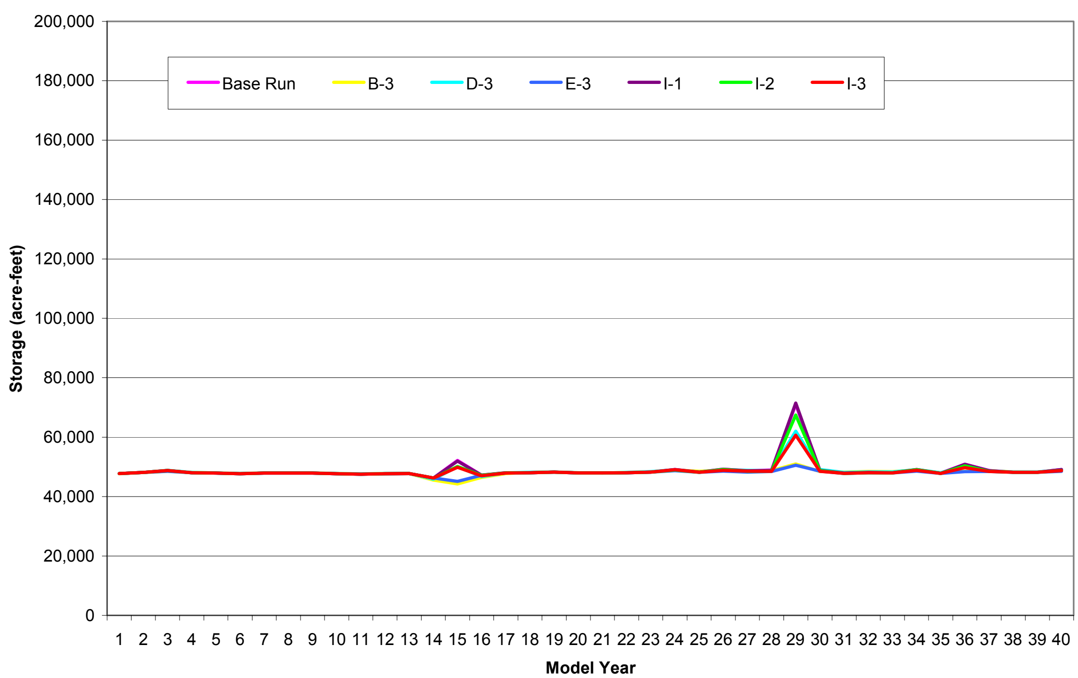


Figure I.D-12: Albuquerque Average Annual Flow (Model Year 1-40)

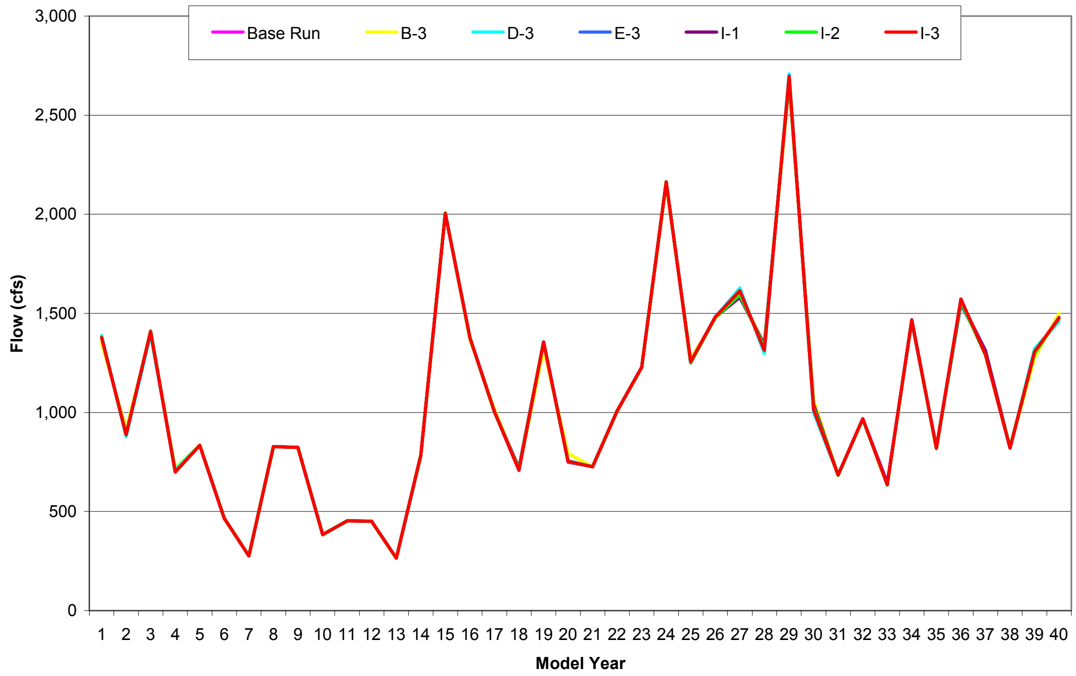


Figure I.D-13: Chamita Average Annual Flow (Model Year 1-40)

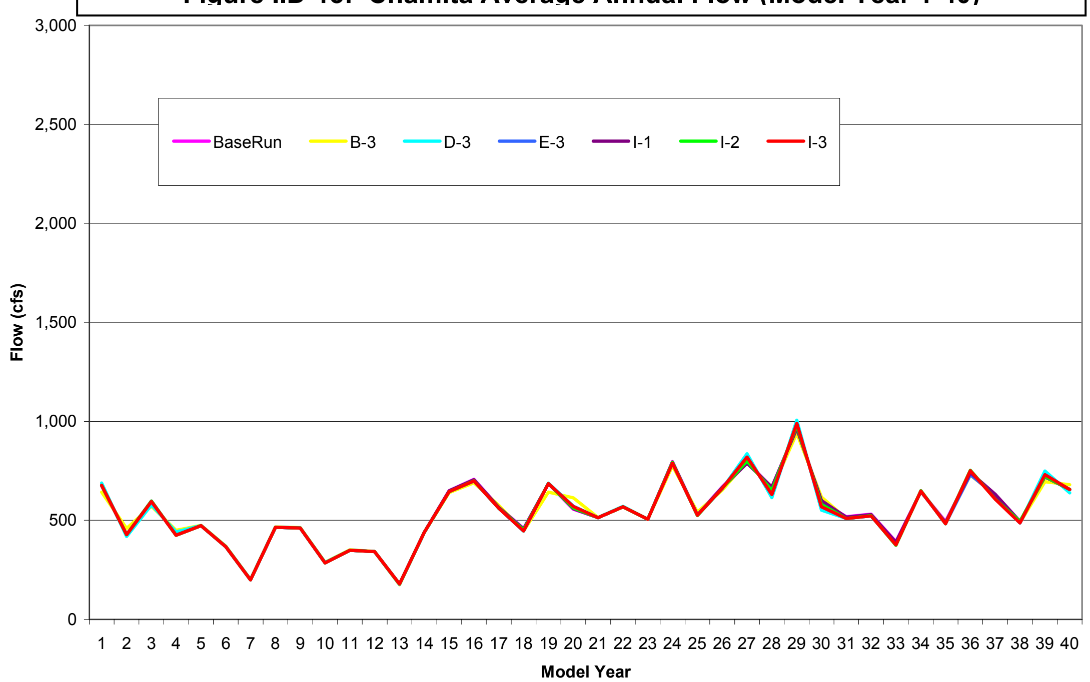


Figure I.D-14: El Vado Average Annual Flow (Model Year 1-40)

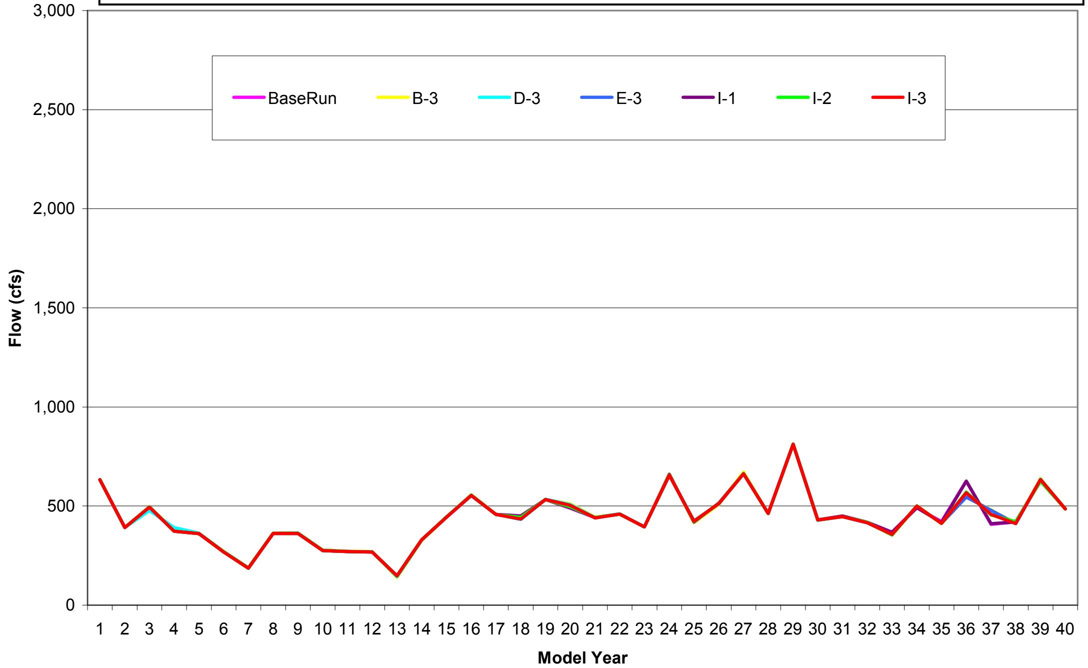


Figure I.D-15: Otowi Average Annual Flow (Model Year 1-40)

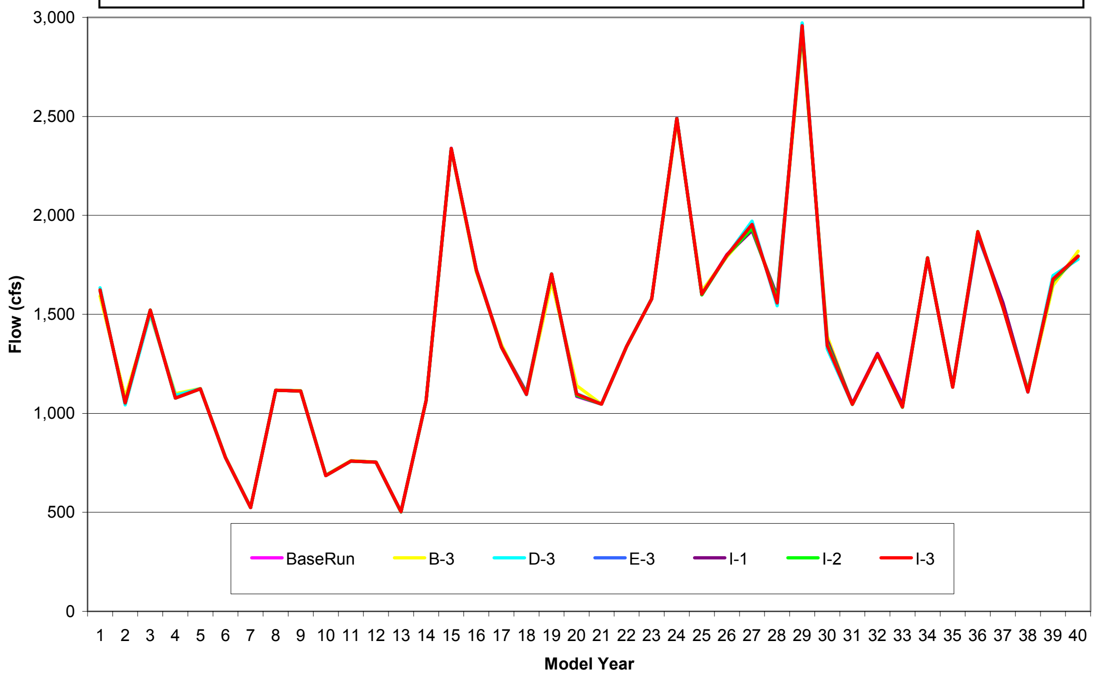
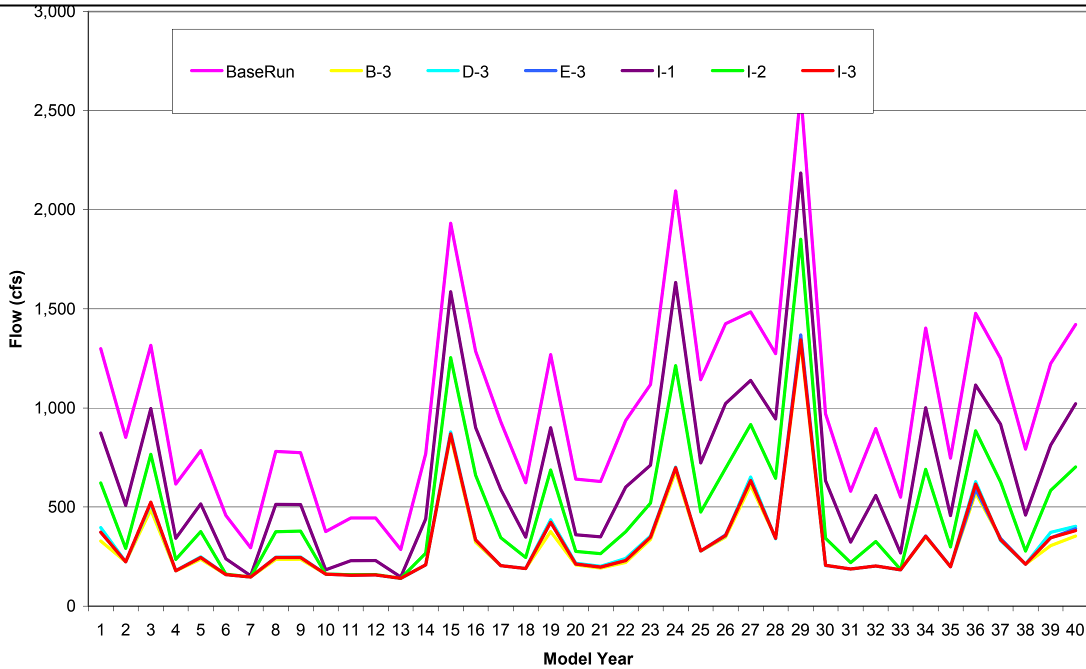


Figure I.D-16: San Acacia Average Annual Flow (Model Year 1-40)



12.0 ATTACHMENT E TABLES

Table I.E-1: Abiquiu Average Annual Pool Elevation (ft) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	6,173.9	6,197.6	6,194.0	6,195.1	6,179.1	6,191.1	6,195.1
Max	6,213.7	6,219.0	6,215.7	6,216.1	6,213.8	6,213.8	6,216.0
Min	6,158.3	6,157.6	6,160.4	6,160.6	6,160.3	6,160.3	6,160.6
Mean	6,179.9	6,192.9	6,190.1	6,191.0	6,182.8	6,188.2	6,191.1
25th percentile	6,171.8	6,179.1	6,176.2	6,177.0	6,174.5	6,178.1	6,177.8
75th percentile	6,189.1	6,202.6	6,200.9	6,201.5	6,192.3	6,193.6	6,201.5

Table I.E-2: Cochiti Average Annual Pool Elevation (ft) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	5,339.0	5,339.1	5,339.1	5,339.0	5,339.0	5,339.0	5,339.0
Max	5,349.9	5,341.2	5,346.6	5,341.1	5,349.9	5,348.6	5,346.0
Min	5,337.4	5,335.4	5,337.0	5,336.3	5,337.4	5,337.4	5,337.4
Mean	5,339.4	5,339.0	5,339.3	5,339.0	5,339.4	5,339.3	5,339.2
25th percentile	5,338.9	5,338.9	5,338.9	5,338.8	5,338.9	5,338.9	5,338.9
75th percentile	5,339.6	5,339.4	5,339.5	5,339.2	5,339.6	5,339.4	5,339.4

Table I.E-3: El Vado Average Annual Pool Elevation (ft) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	6,859.1	6,869.8	6,867.5	6,869.2	6,860.6	6,866.3	6,867.8
Max	6,889.0	6,888.8	6,888.9	6,889.0	6,889.0	6,889.0	6,889.0
Min	6,802.2	6,802.2	6,802.2	6,802.2	6,802.2	6,802.2	6,802.2
Mean	6,859.4	6,860.8	6,860.5	6,860.4	6,859.3	6,859.9	6,860.2
25th percentile	6,838.8	6,838.6	6,838.6	6,838.8	6,838.8	6,838.8	6,838.8
75th percentile	6,883.6	6,884.7	6,883.9	6,883.9	6,882.9	6,883.6	6,883.9

Table I.E-4: Heron Average Annual Pool Elevation (ft) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	7,154.1	7,152.5	7,152.7	7,154.3	7,154.1	7,154.2	7,154.3
Max	7,184.7	7,185.2	7,185.1	7,184.7	7,184.7	7,184.7	7,184.7
Min	7,065.4	7,052.4	7,058.6	7,065.4	7,065.4	7,065.4	7,065.4
Mean	7,151.2	7,149.5	7,150.4	7,151.3	7,151.2	7,151.3	7,151.3
25th percentile	7,132.3	7,130.5	7,131.5	7,132.3	7,132.3	7,132.3	7,132.3
75th percentile	7,183.2	7,182.9	7,183.1	7,183.0	7,183.2	7,183.0	7,183.0

Table I.E-5: Abiquiu Average Annual Pool Storage (acre-ft) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	47,788.5	108,066.0	95,062.0	100,967.5	56,957.0	89,251.0	100,997.0
Max	159,763.0	182,243.0	167,440.0	169,234.0	160,519.0	160,519.0	168,864.0
Min	26,154.0	24,118.0	27,084.0	27,329.0	26,985.0	26,985.0	27,303.0
Mean	64,011.0	99,308.5	90,930.9	93,417.4	69,542.8	83,643.4	93,622.6
25th percentile	43,104.8	60,853.3	52,136.0	55,287.3	49,550.8	55,519.3	55,941.3
75th percentile	83,418.3	126,698.3	121,259.8	123,024.8	91,736.8	95,196.3	123,038.5

Table I.E-6: Cochiti Average Annual Pool Storage (acre-ft) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	48,042.0	48,132.5	48,147.5	48,013.5	48,041.5	48,037.5	48,025.0
Max	71,023.0	50,925.0	62,020.0	50,564.0	71,501.0	67,493.0	60,653.0
Min	46,258.0	44,194.0	45,847.0	45,131.0	46,255.0	46,255.0	46,258.0
Mean	48,873.1	48,069.6	48,593.1	48,011.5	48,874.7	48,671.8	48,457.6
25th percentile	47,894.8	47,869.0	47,945.3	47,836.0	47,893.3	47,885.5	47,882.0
75th percentile	48,765.0	48,486.8	48,693.0	48,273.0	48,742.0	48,523.5	48,491.3

Table I.E-7: Albuquerque Average Annual Flow (cfs) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	986.4	986.0	983.8	986.1	984.7	983.6	986.1
Max	2,672.4	2,654.6	2,708.2	2,698.1	2,673.3	2,683.8	2,695.5
Min	265.3	263.8	264.9	265.3	265.3	265.3	265.3
Mean	1,067.2	1,067.4	1,067.3	1,066.8	1,067.1	1,066.0	1,066.9
25th percentile	724.9	725.3	723.6	721.7	724.4	723.4	721.6
75th percentile	1,377.0	1,354.1	1,380.7	1,376.6	1,376.2	1,375.1	1,376.6

Table I.E-8: Chamita Average Annual Flow (cfs) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	529.8	533.0	524.6	524.6	527.7	523.8	524.6
Max	969.9	939.6	1006.1	990.0	962.5	977.9	990.0
Min	178.5	174.7	176.3	178.5	178.5	178.5	178.5
Mean	543.6	540.9	541.4	540.9	542.8	541.2	540.9
25th percentile	454.4	456.9	444.1	444.6	452.6	449.7	444.7
75th percentile	658.6	644.0	645.7	650.2	658.4	652.6	650.0

Table I.E-9: El Vado Average Annual Flow (cfs) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	435.2	438.1	437.0	437.5	435.2	442.1	437.6
Max	811.9	811.8	812.1	811.7	811.6	811.7	811.7
Min	147.4	138.9	142.8	147.4	147.4	147.4	147.4
Mean	440.4	440.5	440.2	439.6	440.4	439.7	439.6
25th percentile	366.5	364.9	363.6	362.0	365.5	362.0	362.0
75th percentile	490.0	502.0	500.8	500.6	492.3	497.1	500.4

Table I.E-10: Otowi Average Annual Flow (cfs) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	1,320.2	1,316.9	1,312.1	1,316.1	1,318.3	1,315.7	1,316.2
Max	2,937.4	2,911.7	2,972.4	2,958.0	2,930.7	2,945.8	2,958.0
Min	503.8	500.2	501.6	503.8	503.8	503.8	503.8
Mean	1,375.9	1,374.7	1,374.8	1,374.4	1,375.3	1,374.1	1,374.4
25th percentile	1,061.8	1,077.7	1,060.0	1,061.8	1,061.8	1,061.8	1,061.8
75th percentile	1,676.8	1,650.9	1,698.1	1,684.6	1,676.8	1,678.3	1,684.6

Table I.E-11: San Acacia Average Annual Flow (cfs) (Model Year 1-40)

	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Median	913.1	229.5	243.8	237.6	573.6	375.0	237.6
Max	2,591.4	1,327.4	1,357.5	1,368.7	2,185.7	1,852.0	1,342.7
Min	285.4	139.1	140.0	141.0	146.5	141.1	141.0
Mean	1,004.4	316.5	330.0	326.5	686.0	494.9	326.0
25th percentile	627.6	191.3	197.2	194.8	349.3	259.8	194.8
75th percentile	1,289.4	345.1	359.2	356.0	924.9	666.7	353.5

APPENDIX J

HYDROLOGY AND HYDRAULIC MODELING: FLO-2D, SURFACE WATER/GROUNDWATER

FLO-2D Flood Routing Supporting URGWOPS

Submitted by:

Tetra Tech, Inc.

Surface Water Group

Albuquerque, New Mexico

June 2004

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1.0 FLO-2D Flood Routing for URGWOPS

1.1 Introduction

FLO-2D flood routing models for the Middle Rio Grande have been evolving since the first application of the model to the Isleta reach in 1997. The model development has involved the cooperation, support and funding from a number of agencies including the U.S. Fish and Wildlife Service, the Albuquerque District of the Corps of Engineers, the Bureau of Reclamation and the New Mexico Interstate Stream Commission (ISC). Initial applications of the model focused on specific reaches of the Rio Grande including the San Acacia to San Marcial reach, the Isleta Reach from the Isleta diversion to Belen, and the Corps' application to the Rio Bravo bridge reach. As these applications were reviewed and the Upper Rio Grande Water Operations Review (Review) began in earnest, the benefits of having complete, reach based, flood routing models became more apparent.

In support of the Review, three FLO-2D models have been developed. The first of the three, known as the Middle Rio Grande (MRG) FLO-2D Model, extends from Cochiti Dam to the San Marcial Railroad Bridge. The next model developed, also on the Rio Grande, extends from the Highway 285 Bridge, just north of the Rio Grande / Rio Chama confluence, to the Headwaters of Cochiti Reservoir. Both of these models predict discharge hydrographs for approximately every 500-ft of channel and compute overbank flood inundation. The third, and most recently developed FLO-2D model, is on the Rio Chama extending from below Abiquiu Dam to the confluence with the Rio Grande. This model computes overbank flood inundation and predicts discharge hydrographs for approximately every 200 ft of channel.

From Cochiti Dam to Elephant Butte Reservoir, the Middle Rio Grande (MRG) is about 173 miles in length. In establishing the grid system for this reach, as well as the other two reaches, it was necessary to balance spatial resolution with model run time. The factors in choosing a grid element size include the number of grid elements, discharge flux, floodplain surface area, digital terrain model (DTM) resolution, cross section spacing and desired flood area resolution. For the two Rio Grande models a 500-ft grid system was selected. The MRG model consists of 29,998 elements with 1,637 channel elements and the Above Cochiti model has 3,685 elements with 312 channel elements. For the Rio Chama model a 200-ft grid system consisting of 16,284 elements with 721 channel elements was selected. The smaller grid element size for the Chama model was implemented largely due to recent improvements in computer processor speeds as well as, recent efficiencies implemented in FLO-2D pre- and post-processor programs.

The FLO-2D program enhancements include processor programs to facilitate modifying the grid element attributes. These are a graphical working environment (FLOENVIR), grid developer system (GDS) and an inundation map display program (MAPPER). The GDS was created to generate grid systems from DTM points and assign elevations to the grid elements based on a user prescribed numerical filters. The FLOENVIR was designed to graphically edit the large data bases involving the floodplain roughness, infiltration and levees. To display the maximum flood depths and velocities, the water surface elevations and maximum area of inundation, the MAPPER program was developed to plot line contours and shaded contours. The Mapper contour plots are saved as shape files that can be imported into ArcView.

Spatial variable data for the Middle Rio Grande and its floodplain include a wide array of topographical, geomorphological, biological and hydrographical data sets. The available data includes detailed digital terrain models, topographic mapping, controlled aerial photography, field survey data such as river cross sections, geologic data such as floodplain alluvium and processed/interpreted data such as vegetation mapping. These data bases have been incorporated into the FLO-2D data input files.

While the Rio Grande FLO-2D models have relatively large grid elements, they are sufficiently detailed and accurate to conduct hydrograph flood routing and flood inundation analysis in support of the Review. The model will provide accurate estimates of in-channel discharge, area of inundation and water surface elevations. Estimated water losses include free surface water evaporation and infiltration seepage from the channel and floodplain. This report discusses model development, calibration and assumptions used in the application of the models supporting the Review.

1.2 FLO-2D Model Description

FLO-2D is a simple volume conservation, two-dimensional flood routing model that distributes a flood hydrograph over a system of square grid element (tiles). It can be a valuable tool for delineating flood hazards, regulating floodplain zoning or designing flood mitigation. FLO-2D numerically routes a flood hydrograph while predicting the area of inundation and simulating floodwave attenuation. The model is effective for analyzing river overbank flows, but it can also be used to analyze unconventional flooding problems such as unconfined flows over complex alluvial fan topography and roughness, split channel flows, mud/debris flows and urban flooding.

Starting with a basic overland flood scenario, details can be added to the simulation by turning on or off switches for various components. Multiple flood hydrographs can be introduced to the system at any number of inflow points either as a floodplain or channel flow. As the floodwave moves over the floodplain or down channels, flow over adverse slopes, floodwave attenuation, ponding and backwater effects can be simulated.

Channel flow is simulated one-dimensionally with the channel geometry represented by either by natural shaped, rectangular or trapezoidal cross sections. For the three models used to support the Review natural shaped cross sections have been used. Secondary currents, superevelation in bends and vertical velocity distribution are not computed by the channel component. Local flow hydraulics such as hydraulic jumps and flow around bridge piers are also not simulated with the model. FLO-2D does not distinguish between subcritical and supercritical flow because the momentum equation is used in the flood routing and it has no restrictions when computing the transition between the flow regimes. Overland flow is modeled two-dimensionally as sheet flow. Channel overbank flow is computed when the channel capacity is exceeded. An interface routine calculates the channel to floodplain discharge exchange including return flow to the channel. Once the flow overtops the channel, it will disperse to other overland grid elements based on topography, roughness and obstructions.

The two-dimensional representation of the equations of motion in FLO-2D is better defined as a quasi two-dimensional model using a square finite difference grid system. The equation of motion is solved by computing the average flow velocity across a grid element boundary one direction at a time. There are eight potential flow directions, the four compass directions (north, east, south and west) and the four diagonal directions (northeast, southeast, southwest and northwest). Each velocity computation is essentially one-dimensional in nature and is solved independently of the other seven directions. The individual pressure, friction, convective and local acceleration components in the momentum equation are retained. More discussion of model solution and constitutive equations is presented in the FLO-2D Manual which can be downloaded at the FLO-2D website.

The differential form of the continuity and momentum equations in the FLO-2D model is solved with a central, finite difference scheme. This explicit algorithm solves the momentum equation for the flow velocity across the grid element boundary one element at a time. Explicit numerical schemes are simple to formulate but usually are limited to small timesteps by strict numerical stability criteria. Finite difference explicit numerical schemes require significant computational time when simulating complex flow hydraulics such as fast rising flood waves, channels with non-prismatic features, abrupt changes in slope, tributaries or split flow and ponded flow areas.

The solution domain is discretized into uniform, square grid elements. The computational procedure for overland flows involves calculating the discharge across each of the boundaries in the eight potential flow directions. Each grid element hydraulic computation begins with an estimate of the linear flow depth at the grid element boundary. The estimated boundary flow depth is an average of the flow depths in the two grid elements that will be sharing discharge in one of the eight directions. Although a number of non-linear estimates of the boundary depth were attempted in earlier versions of the model, they did not significantly enhance or improve the results. The other hydraulic parameters are also averaged to compute the flow velocity including flow resistance (Manning's n-value), flow area, slope, water surface elevation and wetted perimeter.

The floodplain flow velocity at the boundary is the dependent variable. FLO-2D will solve either the diffusive wave momentum equation or the full dynamic wave momentum equation to compute the velocity. Manning's equation is then applied in one direction using the average difference in the water surface slope to compute the velocity. If the diffusive wave equation is selected, the velocity is then computed for all eight potential flow directions for each grid element. If the full dynamic wave momentum equation option is applied, the computed diffusive wave velocity is used as the first approximation (the seed velocity) in the Newton-Raphson second order method of tangents for determining the roots of the full dynamic wave equation which is a second order, non-linear, partial differential equation. The local acceleration term is the difference in the velocity for the given flow direction over the previous timestep. The convective acceleration term is evaluated as the difference in the flow velocity across the grid element from the previous timestep. For the FLO2-D models used to support the Review the full dynamic wave momentum equation is applied for all simulations.

FLO-2D is on FEMA's list of approved hydraulic models for riverine and unconfined alluvial fan flood studies. It has been used by a number of federal agencies including the Corps of Engineers, Bureau of Reclamation, USGS, NRCS, Fish and Wildlife Service and the National Park Service. It has been used on hundreds of projects by consultants worldwide. Current model and processor program updates and other modeling information can be found at the website: www.flo2d.com.

1.3 FLO-2D Model Development

1.3.1 FLO-2D Data Base

A partial listing of the agencies and institutions that have acquired or developed spatial data sets for the Middle Rio Grande corridor are listed in **Table J-1**. The Corps of Engineers (Corps), Bureau of Reclamation (BOR), U.S. Geological Survey (USGS) and the New Mexico Interstate Stream Commission (ISC) are the primary agencies responsible for compiling MRG water resource data. **Table J-2** lists the name and contact information for the three mapping consulting firms in Albuquerque that have acquired most of the source photography and topographic data used in the production of the various spatial mapping products. During the past 10 years, it is likely that one of these firms produced the detailed, digital terrain model data and/or digital topographic mapping from low level controlled aerial photography that the FLO-2D grids have been built from. The Bureau of Reclamation and its hydrographic data collection contractors have acquired most of the field-surveyed river cross sectional data used in the models. Tetra Tech, Inc., (formally FLO Engineering) has been the primary hydrographic data collection contractor for Reclamation for the past 12 years. In addition, the Earth Data Analysis Center (EDAC), affiliated with the University of New Mexico, provides services in geospatial technologies. The EDAC clearinghouse provides users with numerous spatial data sets and/or corresponding metadata.

Table J-1. Agencies and Institutions with Spatial Data Resources

Agency/Organization	Contact	Telephone No.	General Information
Corps of Engineers Albuquerque District	Clay Mathers	505-342-3255	GIS Coordinator
	Alvin Toya	505-342-3337	Mapping Coordinator
	Bruce Beach	505-342-3331	H & H Data
Bureau of Reclamation Albuquerque Office	Kristi Smith	505-465-3631	River Cross-Sections
	Robert Padilla	505-465-3626	H & H Data
Bureau of Reclamation Denver, TSC	Debra Callahan	303-445-3645	GIS Data
	Travis Bauer	303-445-3672	River Data
New Mexico State Engineers Office / Interstate Stream Commission	Gar Clark	505-827-6175	GIS Data
	Nabil Shafike	505-764-3868	H & H Data
Middle Rio Grande Conservancy District	Doug Stretch	505-247-0234	GIS Data
	David Ginsler		H & H Data
Fish and Wildlife Service Albuquerque Office	Mike Buntjer	505-346-2525	GIS / H & H Data
	Ric Riester		
University of New Mexico	Julie Coonrod	505-277-3233	H & H / GIS
	Mark Schmidt		
New Mexico Technological Institute	Rob Bowman	505-835-5992	H & H

Table J-2. Mapping Consulting Firms

Firm Name	Contact	Telephone No.
Bohannnan Huston, Inc	Dennis Sandin	505-823-1000
Thomas R. Mann & Associates	Tom Mann	505-266-7757
Pacific Western Technologies (formerly Koogle & Pouls Engineering)	Dick Coffey	505-294-5051
Tetra Tech, Inc	Doug Wolf Walt Kuhn	505-881-3188

On May 12, 1992, the BOR obtained aerial photography of the river and floodplain to document the area of inundation resulting from a “higher than normal” release from Cochiti Reservoir. The average daily discharge from this release was estimated to be approximately 7,000 cfs at the Albuquerque gage, about 5,700 cfs at San Acacia gage and 5,000 cfs at San Marcial gage. The visible area of inundation has been digitized from this photographic data set. This is one of the few data sets that are available for use in calibrating flood routing and hydraulic models in this reach of the Rio Grande. This data set was used in 1999 to calibrate the area of inundation predicted by the FLO-2D model between San Acacia and San Marcial, New Mexico. Calibration results indicated a high correlation between the FLO-2D predicted area of inundation and that estimated from the BOR aerial photography for equivalent predicted and measured discharges at San Acacia and San Marcial. This data set is now essentially obsolete because of channel narrowing, cross section changes, floodplain aggradation, and loss of channel conveyance capacity. Channel morphology changes since 1992 have been pronounced in this reach and are particularly significant south of the Highway 380 Bridge and specifically from Tiffany Junction to San Marcial.

1.3.2 DTM Data Base

To assemble the FLO-2D data files, voluminous topographic and cross section data were compiled. Initially the grid system was overlaid and assigned elevations based on digital topographic mapping that the Corps of Engineers and the Bureau of Reclamation had available. These digital terrain models (DTM) were developed, in some instances using photogrammetry (from aerial photography) and others using remotely sensed data (LIDAR) during the 1990's and early 2000's by the agencies. Through a combination of the various aerial surveys, contour maps with two-foot contours were developed and overlaid with a 500-ft grid system for the two Rio Grande FLO-2D models. Using Bently's SelectCADD InRoads software, each grid element was assigned a representative elevation and horizontal state-plane geometry (NM State Plane Central zone NAD 83 ft) coordinates. The Corps provided both ASCII data files and hard copies of the maps with the overlaid grid system. The same process was invoked for the Rio Chama Model, however a 200-ft grid system was used for this reach. **Table J-3** lists the DTM data sets that were used to create the FLO-2D grid systems for the three models supporting the Review.

Table J-3. DTM Data Sets used for FLO-2D Grid Development

Mapping Project	Extents	Brief Description
COE Mapping Reach6 (TRM for COE)	Rio Grande corridor - Cochiti Dam to North Bernalillo County Line	Digital mapping – 2' contour topography, CADD files, 2 ft natural color digital orthopotography – photogrammetry (2001)
Bernalillo County /AMAFCA Digital Mapping (BHI for COE)	Bernalillo County	Digital mapping – 2' contour topography, CADD files, 2 ft natural color digital orthopotography – LIDAR & photogrammetry (1999 –2000)
Belen Mapping (PWT for COE)	Rio Grande corridor & floodplain – Rio Bravo Bridge to Pipelines south of Belen	Digital mapping – 2' & 4' contour topography, CADD files, 2 ft B/W digital orthopotography – photogrammetry (1995)
COE Mapping Reach 7 (TRM for COE)	Rio Grande corridor & floodplain Railroad bridge south of Belen to Socorro Diversion Channel	LIDAR topography, 6 to 9 meter post spacing, No CADD files, 2 ft natural color digital orthopotography 1998-1999
Escondida to South Boundary BDA (PWT for COE, BOR,)	Rio Grande corridor – Escondida bridge to the South Boundary of Bosque del Apache NWR	1992 Agg/Deg Photography used to create digital mapping, No Cadd files, 2 ft B/W digital orthopotography - 1997
South Boundary BDA to EB 27 (PWT for BOR)	Rio Grande corridor and floodplain	Digital mapping – 2' contour topography, CADD files, 2 ft B/W digital orthopotography – photogrammetry (1997)
COE Mapping Reach 4 (TRM for COE)	Rio Grande corridor - Rio Chama confluence to Cochiti Reservoir headwaters	Digital mapping – 2' contour topography, No CADD files, 2 ft natural color digital orthopotography – photogrammetry (2000)

Table J-3. DTM Data Sets used for FLO-2D Grid Development		
Mapping Project	**Extents**	**Brief Description**
COE Mapping Reach 3 (TRM for COE)	Rio Chama corridor – Abiquiu Dam to Rio Grande confluence	Digital mapping – 2' contour topography, CADD files, 2 ft natural color digital orthopotography – photogrammetry (2003)

When the FLO-2D Grid Development System (GDS) filters were developed in 2002 the DTM database was recompiled, re-projected, and parsed from the six different mapping efforts shown in **Table J-3**. Each DTM data set represented a specific reach of the Middle Rio Grande. The DTM data sets were originally compiled in various formats and had different reference elevation datums. The data sets were converted to a consistent datum (the New Mexico State Plane NAD 1983 horizontal and NAVD 1988 vertical reference). When necessary, the Corps of Engineers' software "Corpscon" was applied to rectify the data between different datums. The development of the GDS was an improvement over the use of an external CADD program to assign grid element elevations. CADD programs tended to overestimate the floodplain surface elevations by assigning the elevation of the surface directly over the center of grid element. The GDS DTM point filter scheme was designed to compute the average of DTM points after the high or low elevation DTM points within a prescribed radius of the grid element had been filtered out. The GDS was later used to re-assign grid element elevations to the entire MRG FLO-2D grid system. The Above Cochiti model and the Rio Chama model also have grid elevations derived using the GDS.

The resolution of the DTM data varies by reach. However, within the active floodplain for all three models the intent of the original mapping efforts was to have the aerial mapping contractors generate 2-ft contour interval digital mapping. This infers that, at worst, the points in the DTM data base files should be accurate within plus or minus one foot. Correspondingly, the FLO-2D water surface results should generally be considered to be accurate to plus or minus 1 foot. The reach from Belen to San Acacia diversion dam was collected using LIDAR techniques and did not have the same quality control as the photogrammetry methods used on the rest of the Middle Rio Grande floodplain.

For the MRG model the conglomeration of DTM data was imported into GDS and several filter scenarios were tested to determine the most appropriate filter scheme to use. The test objective was to apply the lowest representative floodplain elevation to the individual grid elements. One of the nine DTM files was imported to the GDS and the grid element elevations were assigned using the standard deviation as the maximum elevation limit filter, a two grid element radius and a minimum of 50 points. When the grid element elevations are assigned, statistics are computed for the number of DTM points within the prescribed filter radius. When applying a filter to the DTM data, the filter radius is expanded until the prescribed minimum number of DTM points is encountered. Based on the selected filter criteria, all the points greater the standard deviation or the prescribed maximum difference in elevation above the mean are discarded and the mean elevation is recomputed and assigned to the grid element. Various combinations of the maximum difference above the mean, the minimum number of points and the radius of influence were tested in an attempt to minimize the floodplain elevation. This was accomplished by comparing all the floodplain elevations in FPLAIN.DAT with the original standard deviation filter results. By summing all the differences in elevation between the grid elements in the two FPLAIN.DAT files, the lowest set of floodplain grid elevations could be determined. The best combination of filter criteria was the selection of maximum elevation difference of 1.0 ft above the mean elevation, a radius of 2 grid elements and 10 minimum points. This scheme provided the lowest floodplain elevation and was used to assign the remainder of the grid element elevations through the middle Rio Grande, Above Cochiti, and on the Rio Chama.

1.3.3 River Cross Section Data Base

Over 400 cross sections have been surveyed throughout the Middle Rio Grande from Cochiti Dam to Elephant Butte Reservoir. An additional 98 cross sections have been surveyed on the Rio Grande above Cochiti Reservoir. Finally, for the Rio Chama model 49 cross sections were established and surveyed in the spring of 2003. These new sections coupled with 18 sections that were surveyed in 2001 within the San Juan Pueblo comprise the cross section data base for the Chama model. Most of the Rio Grande cross sections were surveyed in conjunction with the Bureau of Reclamation's river maintenance program. For the past 10 years, the BOR and its hydrographic data collection contractors have surveyed the majority of these cross sections. Many of the cross sections are located in groups near specific project areas. When Cochiti Dam was under construction in the early 1970's, a series of cross sections were surveyed to monitor long term channel morphology changes. This set of cross sections is referred to as the Cochiti Lines and are labeled "CO" followed by a number. The first thirty-eight of these lines are numbered sequentially starting at 1 (which is actually within the pool at Cochiti). CO-38 is located upstream of the Interstate 25 Bridge over the Rio Grande just south of Albuquerque. From this location, the remainder of the CO-lines have increasing spacing and are numbered in accordance with Bureau's Aggradation – Degradation (Agg/Deg) Range Lines (e.g. CO-668). Most of the other cross sections within this reach have labels that refer to the nearby community such as Santa Domingo (SD), Isleta (IS), or Socorro (SO). For the most part, recently established lines follow the Agg/Deg numbering scheme. The sections above Cochiti reservoir have a similar naming scheme. The Rio Chama cross sections are named AB 1 through 48. The sections on the San Juan Pueblo are CH1 through CH-18. **Table J-4** provides a list of the cross section abbreviations.

The existing cross section end points have been monumented with rebar and cap and have an adjacent fence post, referred to as a 'tag-line post'. The location and elevation of the end points have been established with control surveys spatially referenced to the New Mexico State Plane Coordinate Grid System (NMSPCGS). All elevation data for the Rio Grande end points was initially referenced to the National Geodetic Vertical Datum (NGVD) of 1929. Subsequently this elevation data has been adjusted to the North American Vertical Datum (NAVD) of 1988 using the coordinate conversion software 'Corpscon'.

Table J-4. Cross Section Abbreviations

Line	Description
CO	Original Cochiti Lines, established in 1972, extend from Cochiti Dam to San Acacia
CI	Cochiti Lines (within and near Cochiti Pueblo (below dam))
SD	Santa Domingo Lines (within and near Santa Domingo Pueblo)
SFP	San Felipe Lines (within and near San Felipe Pueblo)
AR	Angostura Lines – near Angostura Diversion Dam
TA	Santa Ana Lines (within and near Santa Ana Pueblo)
BI	Bernalillo Island Lines – Near NM 44 bridge
BB	Below Bernalillo Lines – Below the village of Bernalillo
CR	Corrales Lines – Near Corrales
CA	Calabacillas Arroyo Lines - Near the confluence
A	Albuquerque Lines (between Bridge Blvd & Rio Bravo)

Table J-4. Cross Section Abbreviations	
Line	**Description**
AQ	Proposed additional Albuquerque Lines (between Moñtano and Isleta diversion Dam)
IS	Isleta Lines (within and near Isleta Pueblo)
LL	Los Lunas Lines – Near Los Lunas restoration site
CC	Casa Colorado Lines
AH	Abeyta's Heading Lines
LJ	La Joya Lines – within and near La Joya Wildlife Refuge
RP	Rio Puerco Lines – Near the confluence
SA	San Acacia Lines – D/S of the diversion dam to ~ Socorro
SO	Socorro Lines – Socorro to the San Marcial RR bridge
FC	Fort Craig Lines – Below San Marcial RR bridge – near the old Fort Craig
EB	Elephant Butte Lines – Between the San Marcial RR bridge & the Reservoir
SI	San Idelfonso Lines
SC	Santa Clara Lines
AG	Arroyo Guachapange Lines
SR	Santa Cruz River Lines
VD	Vigil Ditch Lines
RC	Rio Chama Confluence Lines
EL	Espanola Lines
CH	Rio Chama Lines within San Juan Pueblo
AB	Rio Chama below Abiquiu Lines

All cross section point data within the three FLO-2D models are horizontally referenced to the NMSPCGS Central zone NAD 83 ft. All elevations are referenced to NAVD 88 ft.

Although the GDS now includes a low elevation filter, it did not initially have a filter for low floodplain elevations. Although DTM point elevations in canals and ditches can have an effect on the assigned floodplain elevations, these were generally ignored due to the relatively limited spatial extent of these features. More importantly, however, the river channel DTM point elevations in the data base collected at low river flow conditions could effect the river bank floodplain elevations. Along the river channel, floodplain grid elements may have been assigned low elevations. This may also occur where old channel features are located such as abandoned meander bends and oxbows. The grid element floodplain elevations along the river channel were reviewed. Elevations that appeared to be significantly lower (2 ft or more) than surrounding floodplain elevations (both inside and outside the levee system) were adjusted.

To further check the elevations along the river, a new output file CHANBANKEL.CHK was created that lists the difference between the grid element floodplain elevations and the cross section top of bank elevation when the difference is greater than 1 ft. A review of this file resulted in further adjustments in the grid element floodplain elevations. This file was also used to review cross section adjustments during model calibration. Changes to the grid element floodplain elevations were made with the FLOENVIR processor using the floodplain elevation editor.

High resolution flood routing and the prediction of overbank flood inundation require adequate cross section coverage. Ideally there would be a surveyed cross section for each of the channel elements within the FLO-2D models, but this would be cost prohibitive. There are 354 surveyed cross sections currently in the MRG FLO-2D model (**Table J-5**). These sections have been distributed to the 1,637 channel elements in the model. There is approximately one cross section for every four channel elements. In a few locations there are two or more surveyed cross sections within a 500 ft channel element. In this case, only one cross section can be assigned to the channel element. There are 9 LL-lines at the Los Lunas Restoration site (4/02) and 25 new Albuquerque (AQ) cross sections (9/03) that have been recently surveyed. The 25 new Albuquerque lines are listed in **Table J-6**. These cross sections, in the reach from Montano Bridge to the north boundary of the Isleta Pueblo, do not have surveyed endpoint coordinates as of this writing and are not incorporated into the MRG FLO-2D model. The ratio of surveyed cross sections to “channel” grid elements is about one to three for the Above Cochiti model and about one to ten for the 200 foot grid Rio Chama model.

Table J-5. Middle Rio Grande Cross Sections

Cross Section		Date[1]	Cross Section		Date[1]	Cross Section		Date[1]
CI	27.1	8/24/98	SFP	194	10/20/89	CO	28	8/13/99
CI	29.1	8/24/98	CO	19	9/17/98	BI	284	5/31/00
CI	36.1	8/23/98	SFP	197	10/20/89	BI	286	5/31/00
CI	37.2	8/24/98	SFP	198	10/20/89	BI	289	5/31/00
CI	40	8/26/98	SFP	199	10/20/89	BI	291	8/14/99
CI	41	8/26/98	SFP	200	10/20/89	BI	292	8/15/99
CI	M1	9/13/99	AR	203	1/18/00	BI	293	8/15/99
CI	M4	9/13/99	AR	204	1/18/00	BI	294	8/18/99
CI	M7	9/14/99	AR	205	1/18/00	CO	29	8/15/99
CI	M10	9/14/99	AR	206	1/18/00	BI	296	8/18/99
CO	5	9/18/98	AR	207	1/18/00	CO	30	9/15/98
CO	6	9/18/98	AR	209	1/18/00	CO	31	9/24/98
CO	7	9/18/98	AR	211	1/18/00	CO	32	9/24/98
CO	8	9/18/98	AR	214.5	1/18/00	CO	33	9/24/98
SD	M1	8/10/99	AR	215	1/19/00	CO	34	9/29/98
SD	M3	8/10/99	AR	216	1/19/00	CA	1	6/2/96
SD	M6	8/10/99	AR	216.5	1/19/00	CA	2	6/2/96
SD	M10	9/2/99	AR	217.5	1/19/00	CA	3	6/2/96
CO	9	9/17/98	AR	219.5	1/19/00	CA	4	6/2/96
CO	10	9/17/98	AR	220.5	1/19/00	CA	5	6/3/96
SD	1	6/25/92	AR	222	1/19/00	CA	6	6/3/96
SD	3	6/25/92	AR	224	1/20/00	CA	9	6/3/96
SD	5	6/25/92	CO	22	9/17/98	CA	10	6/4/96
SD	7	2/28/93	AR	227.5	1/20/00	CA	11	6/4/96
SD	8	2/28/93	AR	229	1/20/00	CA	12	6/1/00
SD	10	6/26/92	AR	230	1/20/00	CA	13	6/4/96
SD	12	6/26/92	AR	232	1/21/00	CO	35	6/1/00
SD	14	6/26/92	AR	233	1/21/00	CA	36	6/2/00
SD	16	6/26/92	AR	234	1/21/00	A	1	5/19/99
SD	17	3/1/93	AR	235	1/21/00	A	4	5/20/99
SD	19	3/1/93	CO	23	9/18/98	A	6	5/20/99
SD	20	6/27/92	CO	24	8/18/99	CO	37	6/2/00
SD	22	6/27/92	TA	249	8/18/99	IS	658	6/22/98

Table J-5. Middle Rio Grande Cross Sections								
Cross Section		Date[1]	Cross Section		Date[1]	Cross Section		Date[1]
SD	25	6/27/92	TA	250	8/18/99	CO	668	6/22/98
SD	27	6/27/92	TA	252	8/4/99	IS	675	6/22/98
SD	30	3/1/93	TA	253	8/4/99	IS	678	6/22/98
SD	32	3/1/93	TA	253.9	8/19/99	IS	688	6/22/98
SD	33	3/1/93	TA	255	8/5/99	IS	689	6/22/98
SD	34	3/2/93	CO	25	8/5/99	IS	691	6/22/98
SD	35	3/2/93	TA	258.2	8/12/99	IS	705	6/22/98
SD	36	3/2/93	TA	259	8/11/99	CO	713	6/22/98
SD	37	3/2/93	TA	259.4	8/19/99	CO	724	6/22/98
SD	39	3/2/93	CO	26	5/30/00	CO	738.1	6/21/98
SD	43	3/3/93	TA	262	8/19/99	IS	741	6/21/98
SD	44	3/3/93	TA	263	5/30/00	IS	748	6/21/98
SD	45	6/28/92	TA	264	8/19/99	IS	752	6/21/98
SD	47	6/28/92	TA	265	5/30/00	IS	765	4/02
CO	14	9/16/98	TA	267	5/30/00	IS	772	4/02
CO	15	9/16/98	CO	27	5/30/00	IS	782	4/02
CO	16	9/16/98	TA	269	5/30/00	IS	787	4/02
SFP	170	6/29/92	TA	270	5/30/00	IS	797	4/02
SFP	172	8/25/98	TA	273	6/2/00	IS	801	6/20/98
SFP	173	6/29/92	TA	274	6/2/00	IS	806	6/20/98
SFP	178	10/18/89	TA	276	6/2/00	IS	815	6/19/98
SFP	179	10/19/89	TA	278	5/31/00	IS	833	6/19/98
SFP	180	10/19/89	TA	279	8/13/99	IS	841	6/19/98
SFP	181	10/20/89	TA	280	5/31/00	IS	849	6/18/98
CO	18	9/17/98	TA	281	8/13/99	IS	849	6/18/98
SFP	193	10/20/89	TA	282	5/31/00	CO	858.1	6/18/98
IS	860	6/19/98	SA	1215	01/02	SO	1491	5/02
IS	864	6/19/98	SA	1218	01/02	SO	1496	5/02
IS	872	6/19/98	SA	1221	01/02	SO	1499	5/02
CO	877	6/17/98	SA	1223	01/02	SO	1502	5/02
IS	880	6/17/98	SA	1224	01/02	SO	1508.9	5/02
IS	884	6/17/98	SA	1225	01/02	SO	1517.2	5/02
IS	885	6/17/98	SA	1226	01/02	SO	1524	5/02
IS	887	6/17/98	SA	1228	01/02	SO	1531	5/02

Table J-5. Middle Rio Grande Cross Sections								
Cross Section		Date[1]	Cross Section		Date[1]	Cross Section		Date[1]
CO	895	6/18/98	SA	1229	01/02	SO	1536	5/02
IS	899	6/18/98	SA	1230	01/02	SO	1539	5/02
IS	908	6/18/98	SA	1231	01/02	SO	1550	5/02
CO	926	9/1/98	SA	1232	01/02	SO	1554	5/02
CC	924	3/25/96	SA	1236	01/02	SO	1557	5/02
CC	927	3/25/96	SA	1243	01/02	SO	1560.5	5/02
CC	930	3/25/96	SA	1246	01/02	SO	1566	5/02
CC	932	3/25/96	SA	1252	01/02	SO	1572.5	5/02
CC	934	3/25/96	SA	1256	01/02	SO	1576	5/02
CC	936	3/25/96	SA	1259	01/02	SO	1581	5/02
CC	939	3/26/96	SA	1262	01/02	SO	1583	5/02
CC	941	3/28/96	SA	1268	01/02	SO	1584	5/02
CC	943	3/25/96	SA	1274	01/02	SO	1585	5/02
CC	945	3/25/96	SA	1280	01/02	SO	1596.6	5/02
CO	966	9/13/98	SA	1292	01/02	SO	1603.7	5/02
CO	986	9/1/98	SO	1298	5/02	SO	1626	5/02
CO	1006	9/1/98	SO	1302	5/02	SO	1641	5/02
AH	1	2/11/94	SO	1306	5/02	SO	1645	5/02
AH	2	2/10/94	SO	1308	5/02	SO	1650	5/02
AH	3	2/10/94	SO	1310	5/02	SO	1652.7	5/02
AH	4	2/10/94	SO	1311	5/02	SO	1660	5/02
AH	5	2/11/94	SO	1312	5/02	SO	1662	5/02
AH	6	2/11/94	SO	1313	5/02	SO	1663	5/02
AH	7	2/11/94	SO	1314	5/02	SO	1664	5/02
CO	1026	9/1/98	SO	1316	5/02	SO	1666	5/02
CO	1044	9/1/98	SO	1320	5/02	SO	1667	5/02
CO	1064	9/3/98	SO	1327	5/02	SO	1668	5/02
CO	1091	9/2/98	SO	1339	5/02	SO	1670	5/02
RP	1100	10/5/00	SO	1342.5	5/02	SO	1673	5/02
CO	1104	9/2/98	SO	1346	5/02	SO	1683	5/02
RP	1108	10/5/00	SO	1349	5/02	SO	1692	5/02
LJ	5	9/26/00	SO	1352	5/02	SO	1701.3	5/02
LJ	9	9/26/00	SO	1360	5/02	EB	10	5/02
RP	1128	9/26/00	SO	1371	5/02	EB	12	5/02

Table J-5. Middle Rio Grande Cross Sections

Cross Section		Date[1]	Cross Section		Date[1]	Cross Section		Date[1]
LJ	15	10/5/00	SO	1380	5/02	EB	13	5/02
LJ	20	9/26/00	SO	1394	5/02	EB	14	5/02
RP	1144	12/19/00	SO	1396.5	5/02	EB	15	5/02
RP	1150	10/5/00	SO	1398	5/02	EB	16	6/02
RP	1160	9/29/00	SO	1401	5/02	EB	17	6/02
CO	1164	9/2/98	SO	1410	5/02	FC	1754	6/02
RP	1170	9/29/00	SO	1414	5/02	EB	18	6/02
CO	1179	9/3/98	SO	1420	5/02	EB	19	6/02
RP	1184	9/29/00	SO	1428	5/02	EB	20	6/02
RP	1190	10/5/00	SO	1437.9	5/02	EB	21	6/02
CO	1194	9/2/98	SO	1443	5/02	EB	34	6/02
RP	1201	9/29/00	SO	1450	5/02	EB	23	6/02
RP	1205	9/28/00	SO	1456	5/02	EB	24	6/02
SA	1207	7/13/98	SO	1462	5/02	EB	25	6/02
SA	1209	7/13/98	SO	1464.5	5/02	EB	26	6/02
SA	1210	‘01/02	SO	1470.5	5/02	EB	27	6/02
SA	1212	‘01/02	SO	1482.6	5/02			

[1]Date of Last Survey

Table J-6. Albuquerque Reach Cross Sections	
Line	**River Mile**
AQ-467	187.6
AQ-472	187.1
AQ-476	186.7
AQ-480	186.3
AQ-487	185.6
AQ-492	185.2
AQ-496	184.2
AQ-503	184.0
AQ-507	183.6
AQ-515.5	182.8
AQ-520	182.3
AQ-526	181.7
AQ-531	181.2
AQ-535	180.8
AQ-567	177.8
AQ-572	177.3
AQ-577	176.9
AQ-582	176.4
AQ-589	175.7
AQ-595	175.2
AQ-600	174.7
AQ-606	174.1
AQ-610	173.7
AQ-621	172.7
AQ-625	172.4

1.3.4 Levee Data and Crest Elevations

The Middle Rio Grande levee data base is complete. Using the FLOENVIR program, levee locations and crest elevations were assigned to the grid element flow directions. For reaches where digital photography and DTM's were available, a levee crest elevation profile was generated using the Corridor design software InRoads. The levee crest profile was then linearly interpolated using a projection line from the centroid of each grid element to a perpendicular intersection with the levee alignment to assign levee crest elevations to individual grid elements. Due to the variability of the LIDAR points in the MRG Model - Belen to San Acacia reach, levee data for this reach was obtained from a BOR HEC-RAS hydraulic model. The levee data in this model was based on earlier photogrammetry surveys and the crest elevations were adjusted to the NAVD88 datum. The levee locations with respect to the FLO-2D grid elements were assigned by correlating HEC-RAS cross section locations. A levee crest elevation profile was again generated and linearly interpolated using projections to the levee alignment to assign crest elevations to FLO-2D levee elements. In the San Acacia to San Marcial reach most of surveyed cross sections extend to the levee and a crest profile was created using NAVD88 datum adjusted survey data. This profile was then linearly interpolated using projections to the levee alignment to assign the levee elevation. It should be noted that the DTM data base did not extend to the floodplain outside of the levee system in a portion of this reach. As a result, the boundary of the grid system constituted the levee and levee crest designations were not assigned. Recently, the DTM data base has been expanded and new grid elements have been assigned to the floodplain in the Socorro area.

After the entire levee system for the MRG model was coded into the LEVEE.DAT file, the FLOENVIR was used to check the assigned levee crest elevations with the grid element floodplain elevations on either side of the levee. If the floodplain elevation was higher that the levee crest elevation, the information was reported in the CHANNEL.CHK file. Either the floodplain elevation or the levee crest elevation was then adjusted to eliminate this condition. There is no levee coding in either the Above Cochiti Model or the Rio Chama model, as levees are not prominent in either reach.

1.4 FLO-2D Model Calibration

A number of years of USGS gage record were searched for hydrographs that would support model calibration for both i

- Lack of hourly gage discharge records prior to 1993 and limited diversion data;
- Limited instantaneous peak discharge data after 1989.
- Ungaged tributary inflow that makes it difficult to distinguish between ungaged inflow, return irrigation flow or gaging error;
- Rating curve shift and gaging record discrepancies;
- Poor spatial distribution and a limited number of gages;
- Significant variation in infiltration and roughness characteristics.

The hourly gaging record can create a distorted picture of the volume of water passing the various gages. In particular, the San Acacia and San Marcial gages appear to be subject to a number of variable conditions that affect the rating curve. For example, in 1997 Cochiti Dam released less than 3,000 cfs for 10 days. This hydrograph should be entirely contained within the channel. The gage issues were:

- The Albuquerque gage reports a discharge greater than either Cochiti Dam release or the San Felipe gage for most of the 10 day record.
- Both the Bernardo and San Acacia record discharge exceeds that of the any of the upstream gaging discharge for the recessional limb.
- The San Marcial hydrograph does not reflect the record at San Acacia in magnitude or shape.
- Some of these incongruities may be explained by ungaged inflows, but there is no way to distinguish between inflow contributions and gage problems. In 1998, there was no flow in the Rio Puerco during high flow season, so the Rio Salado would have had to been flowing over 1,000 cfs to account for the increase between the Bernardo and San Acacia gages during the same time that the Rio Puerco had zero flow. In addition, the calibration effort revealed the following gaging inconsistencies:
- The San Felipe gage is reporting several hundred cfs more discharge than the Cochiti gage for a large portion of the hydrograph.
- The Bernardo gage shows a substantial increase in the discharge that is not reflected in either the upstream or downstream gages.

- The San Acacia gage plus the LFCC discharge does not match the shape of the hydrograph at San Marcial and has a number of high flow instantaneous spikes.
- The San Marcial gage record does not have corresponding discharge spikes.

The MRG model was divided into reaches represented by the gaging stations for calibration of the hydrograph timing. Each channel grid element is represented by a hydraulic roughness coefficient (Manning's n-value). N-values represent both friction drag (grain size resistance and bedforms) and form drag (sandbar macroforms, variation in channel geometry, vegetation, etc.). The primary concern related to hydraulic resistance is the potential variation in the n-value over the rising and falling limb of the hydrograph. The change in bedforms from lower regime to upper regime sediment transport can result in a significant reduction in hydraulic resistance. During calibration, channel roughness values were initially adjusted using limiting Froude number criteria. The San Acacia to San Marcial reach was calibrated in a previous project and n-values in this reach were not significantly modified during this calibration effort. The new cross section routine that uses the actual cross section data greatly improved the correlation between the slope, flow area and roughness and reduced the need for significant changes in the n-values during calibration.

Calibration of channel roughness was based on hydrograph timing. Abrupt variations in discharge (either spike increases or a rapid decrease in discharge) can be tracked through the system and used to adjust the n-values. By varying the n-value, the model can improve the replication of the hydrograph spike timing in the observed data. The 'in-channel' flow hydrographs were calibrated first. Then overbank flow hydrographs were calibrated. The final modifications of n-values were accomplished by increasing or decreasing n-values by a percentage for an entire reach.

Overbank flow calibration requires knowledge of the area of inundation for a given hydrograph. The predicted area of inundation can be adjusted by changing the relationship between the slope, flow area and roughness of individual channel elements to adjust the area of inundation along the channel. This was accomplished in the San Acacia to San Marcial reach as presented in a September 16, 2000 BOR report. Unfortunately, none of the other reaches have the supporting aerial photography to calibrate overbank flow conditions.

In the reach from Cochiti Reservoir to Bernalillo Bridge, there should be little to no overbank flooding for discharges less than 7,000 cfs from Cochiti Dam. A new output file was created called OVERBANK.OUT which lists all the channel elements that have overbank flow (i.e. flow depth exceeds bankfull depth) and the first time of occurrence. By reviewing this file for a constant discharge of 7,000.

During this calibration effort, the channel hydraulic conductivity was the focus of infiltration calibration. After calibrating the hydrograph timing with Manning's n-values, accounting for all the tributary inflow, diversions and return flow and estimating the evaporation loss, the channel hydraulic conductivity was adjusted on a reach by reach basis to improve the replication of the hydrograph shape and volume. Channel hydraulic conductivity was calibrated for the in-channel flows first. Minor adjustments to the floodplain hydraulic conductivity were then made for overbank flows.

MRG model calibration was undertaken using the spring runoff hydrographs for 1997, 1998 and 2001. The first calibration was attempted with the 1997 in channel flow hydrograph for the period April 20-30, 1997. The calibration of the five hydrographs were presented in the April, 2002 ISC FLO-2D calibration report. The hydrograph plots were presented in that report appendix. A brief discussion of the calibration runs follow:

1997 Low Flow Hydrograph

For the period from April 20 – 30, 1997 the discharge was in-channel flow and did not exceed a 3,000 cfs release from Cochiti Dam. At San Felipe gage the model underpredicted rising and falling limbs and overpredicted the peak discharge but the timing was good. The model overpredicted the entire hydrograph at Albuquerque by about 300 cfs, but timing was pretty good. The spike was missing from Cochiti Release in measured data. The model underpredicted entire Bernardo hydrograph by 200 to 300 cfs (10%) At the San Acacia gage, either the Rio Salado was flowing (there is no flow in Rio Puerco) or gage is off. The San Marcial record confirmed that the San Acacia gage was poorly calibrated. The Marcial gage report discharges that were too low because there was 2,500 cfs at Bernardo and 3,500 cfs (unlikely) at San Acacia. In summary, the model does a reasonably good job for the reach from Cochiti Dam to Bernardo. It is probable that neither the San Acacia or San Marcial gages reflect the actual flow in the river.

1998 Low Flow Hydrograph

The same data base for 1997 low flow hydrograph was used to predict the discharge for the 1998 low flow hydrograph. The model did good job of replicating the entire MRG for the 1998 low flow hydrograph. This demonstrates that the model was reasonably calibrated for most of the gains and losses in the system. The predicted discharge at San Acacia was slightly overpredicted (**Figure J-1**).

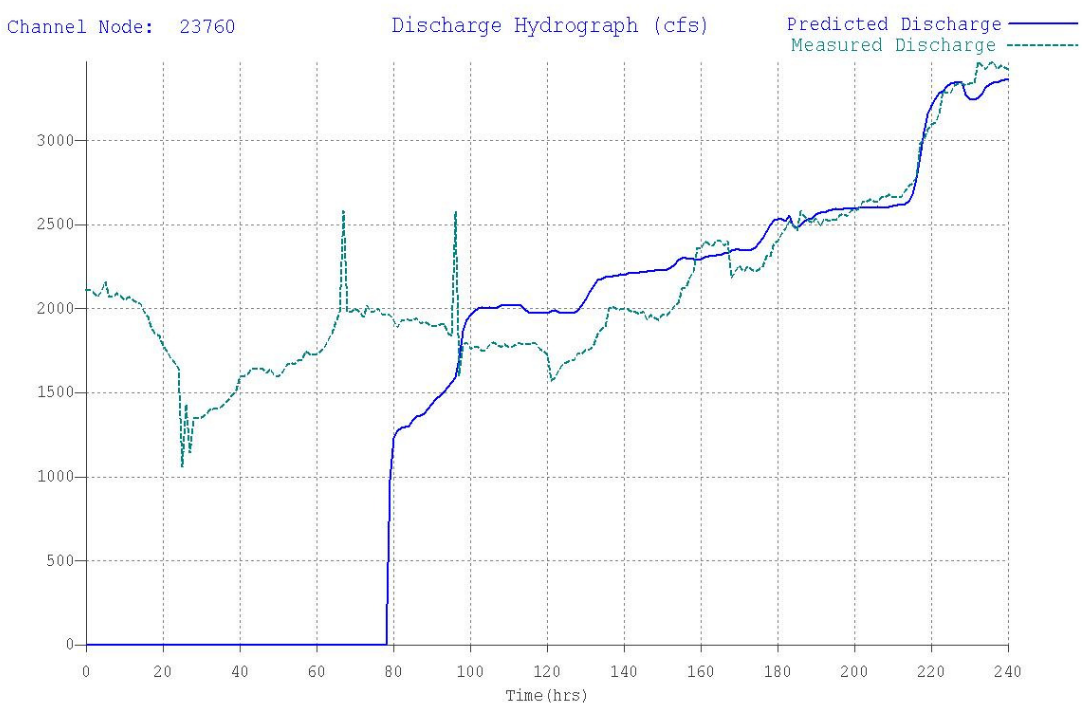

Figure J-1. San Acacia Gage 1998 Measured and Predicted Hydrographs

1997 High Flow Hydrograph

The 1997 high flow hydrograph for 31 days with a peak discharge exceeding 6,000 cfs was simulated. The model predicted the San Felipe and Bernardo measured hydrographs very well. The Albuquerque and

San Acacia gage record were poorly replicated. Overbank flow and the diversion at San Acacia dam may be part of the reason for the poor replication.

1998 High Flow Hydrograph

The 1998 High Flow Hydrograph also exceeded 6,000 cfs. In general, the model did a good job of predicting the shape of the measured hydrograph throughout the system of five gages. The model overpredicted the discharge at the Albuquerque and San Acacia gage and underpredicted the discharge at the Bernardo and San Marcial gages. Based on the previous calibration runs, it was considered inappropriate to increase or decrease the infiltration losses to create a better match.

2001 Hydrograph

The 2001 hydrograph represented a block release of about 4,000 cfs over a two day period. This block release would have been an excellent model test except for the additional Jemez Dam release whose hydrograph was not very well monitored. A one hour time lag was assumed for the Jemez release to arrive at the Rio Grande. The combined peak discharge exceeded 6,000 cfs. The 2001 flood pulse was accurately replicated for the San Felipe (**Figure J-2**) and reasonably reproduced the hydrograph shape at Bernardo and San Acacia. The replication was poor at the Albuquerque and San Marcial gages.

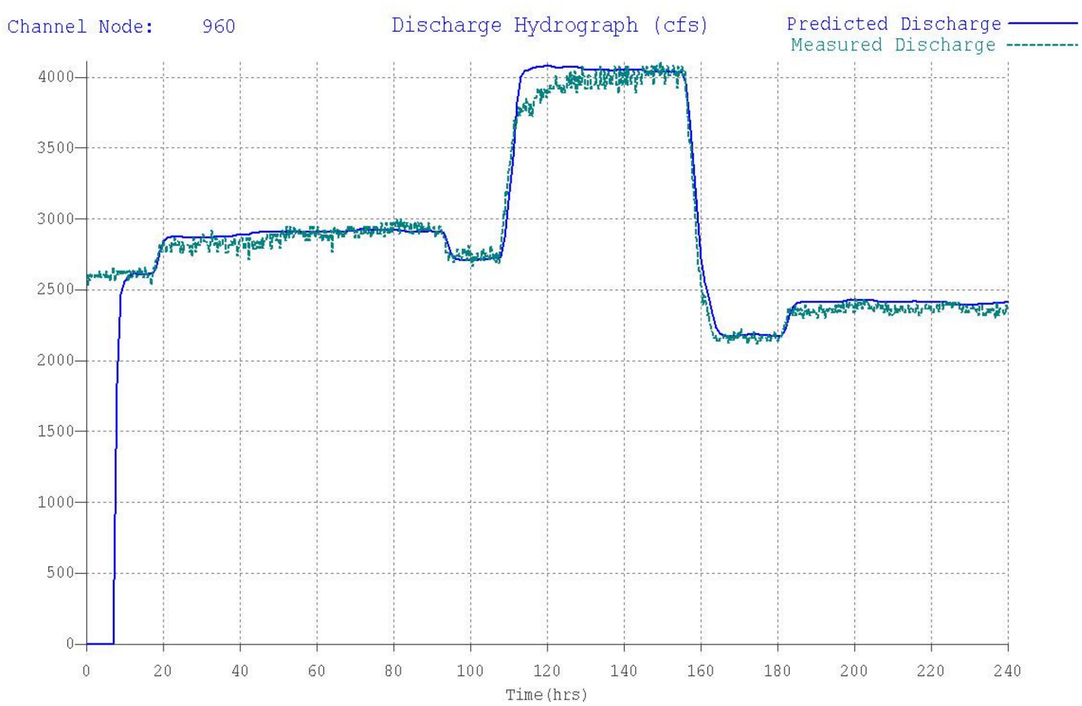

Figure J-2. San Felipe Gage 2001 Measured and Predicted Hydrographs

Overall the model did a reasonably good job of replicating the five calibration hydrographs. One or more gages are poorly replicated for each hydrograph. The San Acacia and San Marcial gages had the poorest replication followed by Albuquerque and Bernardo. The two gages at the lower end of the system are subject to vagaries of the sand bed channel and constant gage shifts.

1.4.1.1 URGWOM Flow Calibration

For the Review additional model calibration was done to verify that FLO-2D predicted discharges would reasonably match discharges from the URGWOM Planning Model. **Figure J-3** through **Figure J-8** show results from this work.

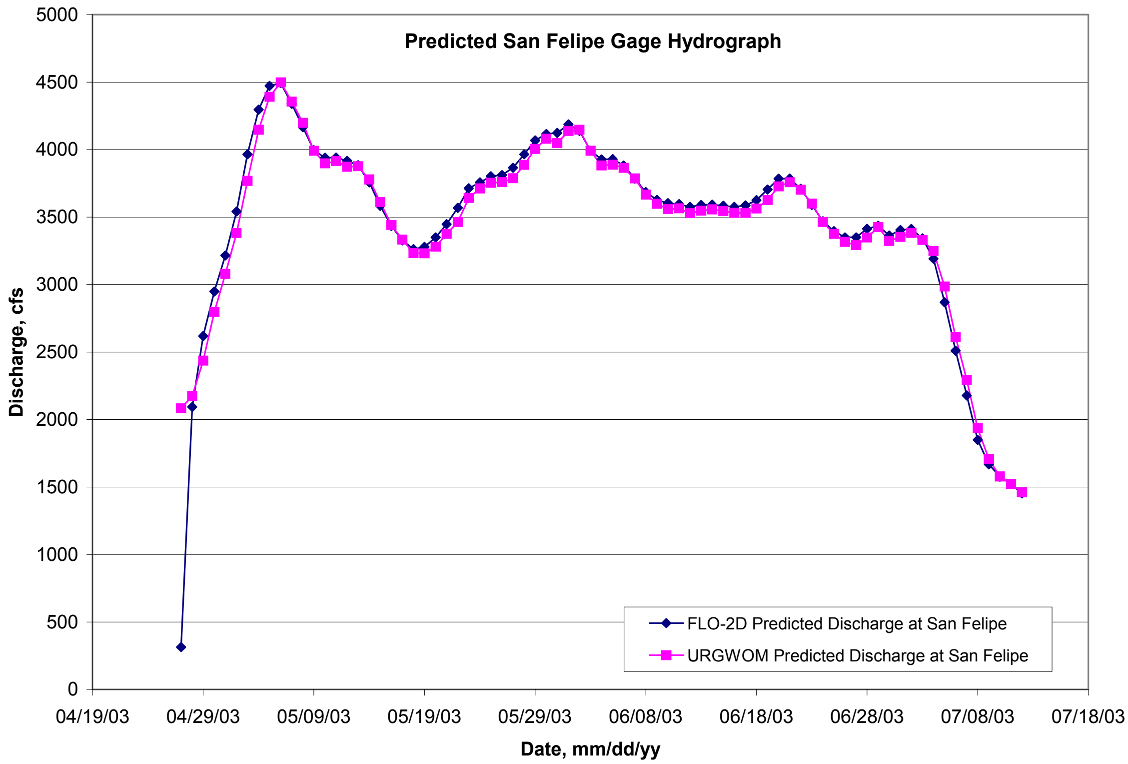

Figure J-3. MRG FLO-2D Hydrograph Replication

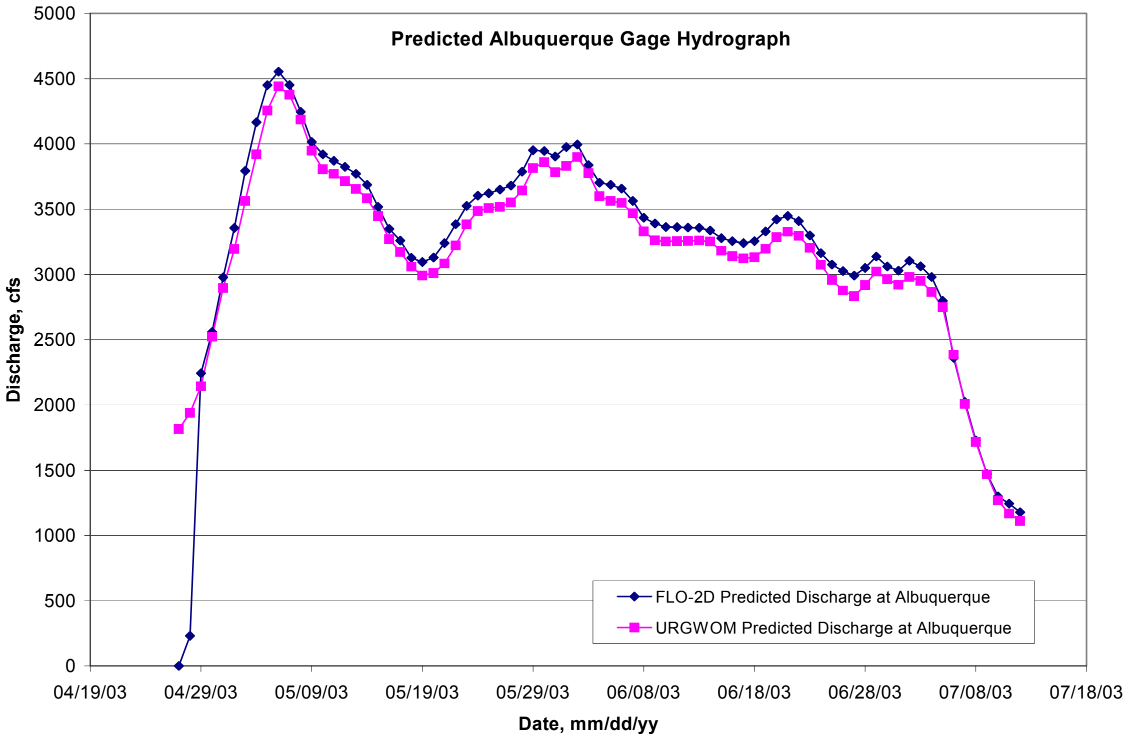

Figure J-4. MRG FLO-2D Hydrograph Replication

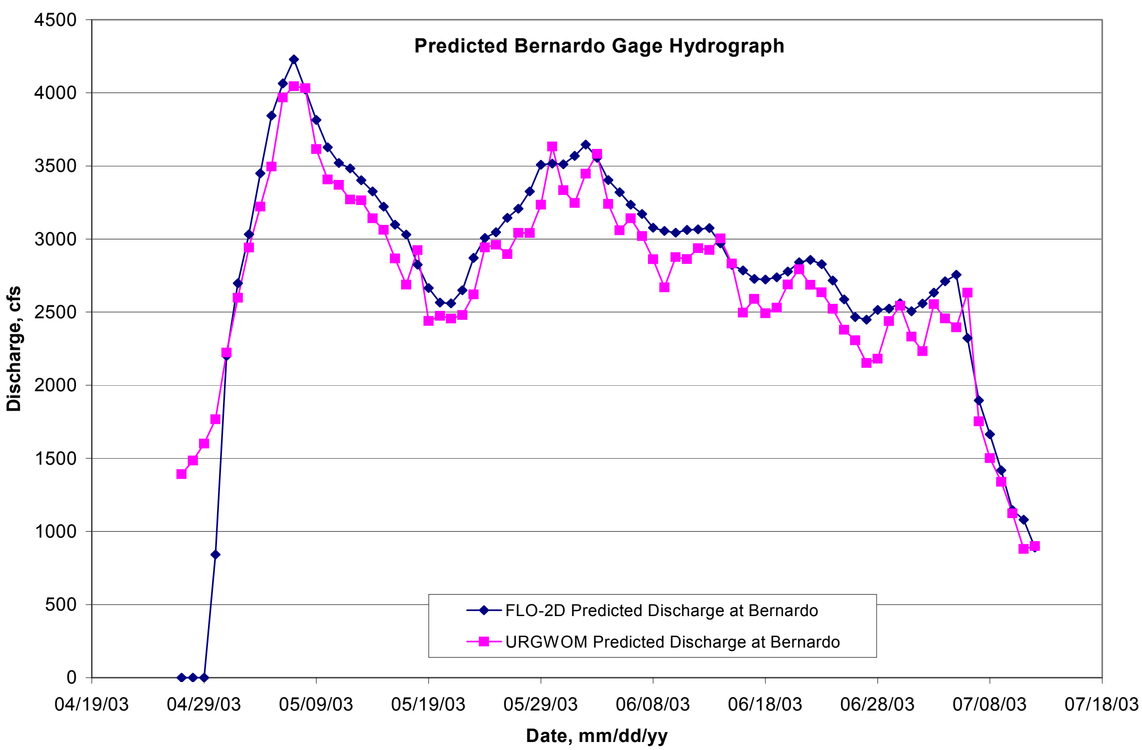

Figure J-5. MRG FLO-2D Hydrograph Replication

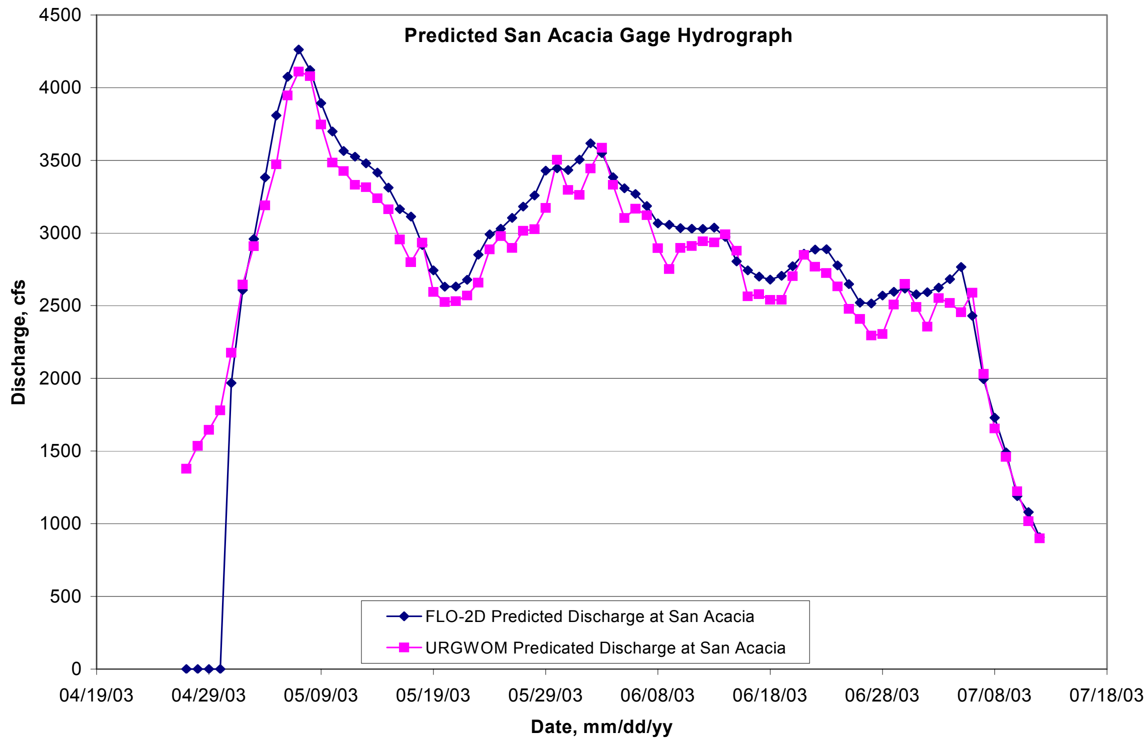

Figure J-6. MRG FLO-2D Hydrograph Replication

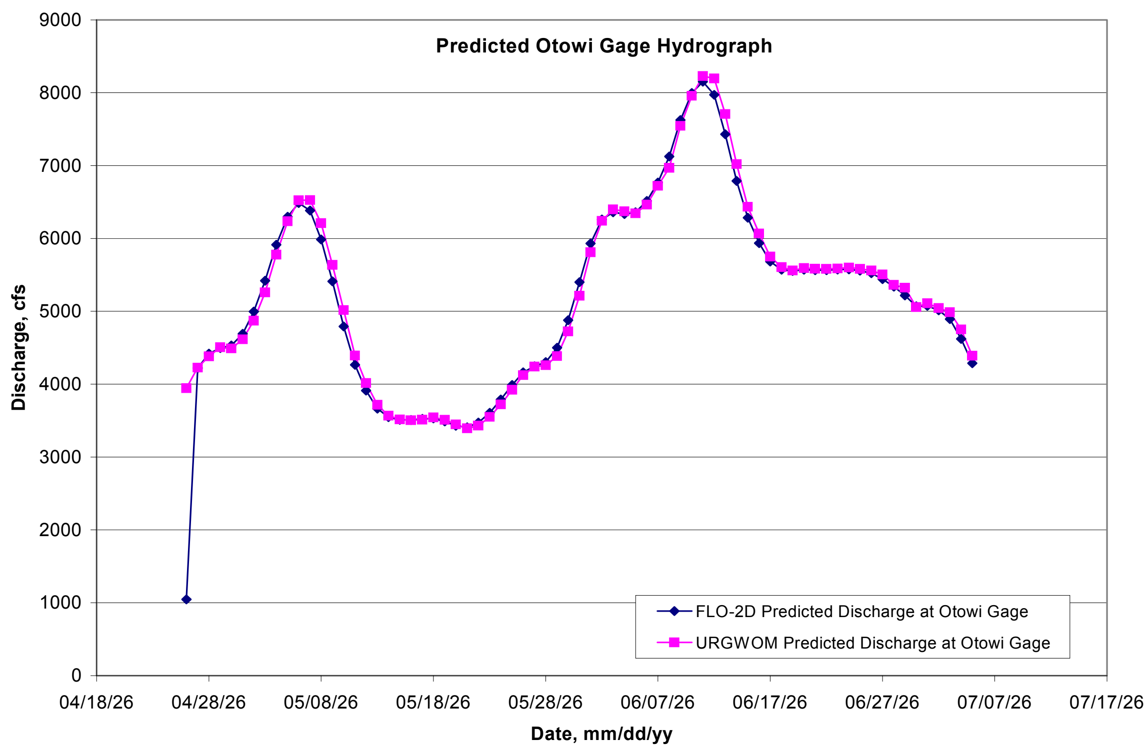

Figure J-7. Above Cochiti FLO-2D Hydrograph Replication

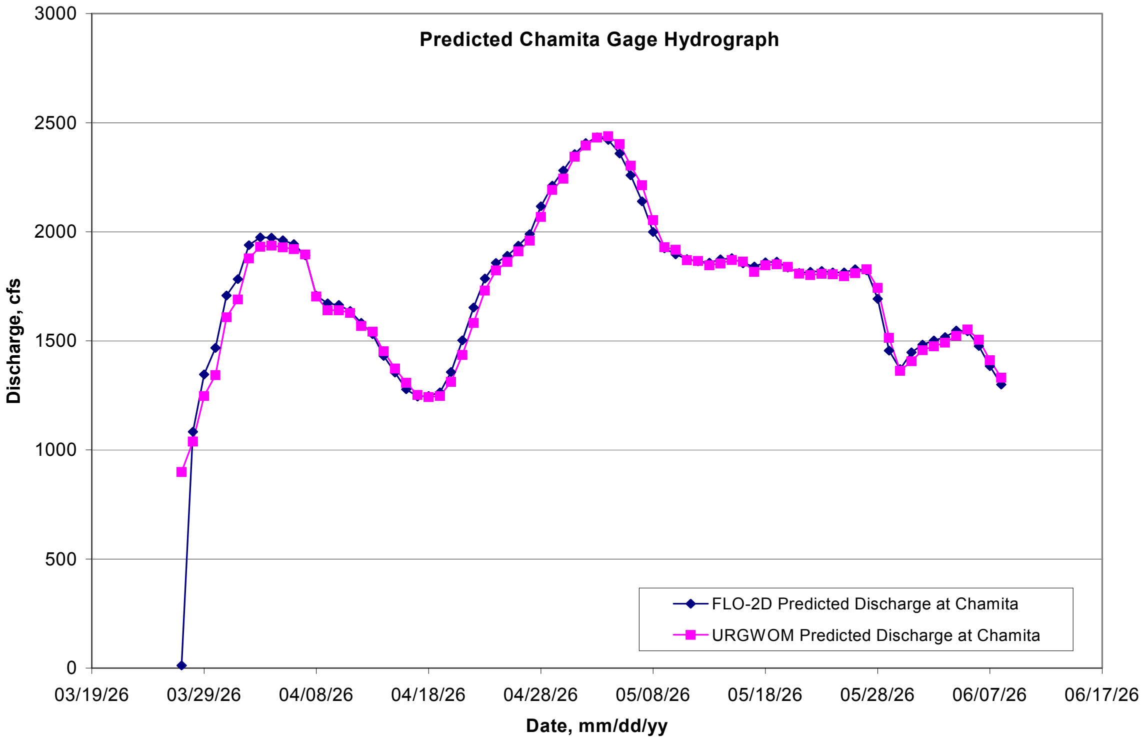

Figure J-8. Rio Chama FLO-2D Hydrograph Replication

2.0 MRG FLO-2D Model Components

2.1 Introduction

A number of FLO-2D model enhancements have been developed in conjunction with the FLO-2D modeling supporting the Review. These include recent improvements to the GDS and MAPPER. The improvements to these two processor programs are extensive and facilitate efficient FLO-2D input file and output file creation. Other enhancements to the FLO-2D model include an evaporation component, irrigation return flows, expanded spatially variable infiltration parameters, depth variable n-value adjustments, and output file details. A brief description of these components is discussed.

2.2 Evaporation

An estimate of free surface evaporation was coded into the MRG FLO-2D model. Previously, channel and floodplain infiltration were the only losses that were computed in the model. The objective of adding the evaporation component was to separate the evaporation from the infiltration loss when calibrating the model. The infiltration loss can then be assumed to be either an increase in groundwater storage or potential loss to plant evapotranspiration. The FLO-2D model tracks the water surface area for both the channel and the floodplain on a timestep basis. To calculate the evaporation loss, the user must specify a mean monthly evaporation (in inches/month or mm/month if using metric units) in the INFIL.DAT file. The only other data requirement is the clock time at the start of the simulation.

James Cleverly of the Department of Biology, University of New Mexico provided estimates of the percentage of daily evapotranspiration on an hourly basis for each month (**Table J-7**). The evaporation loss is assumed to be constant during the hour shown in the table. The evaporation loss is reported at the end of the BASE.OUT and SUMMARY.OUT files in terms of both total evaporation in inches and total volume loss in acre-ft or cubic meters. A mean monthly evaporation for each month was derived from various sources such as the Rio Grande Joint Investigation General Report. For example:

The mean monthly evaporation for Elephant Butte 1917-1936 for May: 12.77 inches.

The mean monthly evaporation for Albuquerque 1926-1932 for May: 10.73 inches.

The average for the two records was approximately 11.75 inches. A mean monthly evaporation of 8.22 inches was used in the FLO-2D model for May using a pan evaporation coefficient of 0.7. The mean monthly evaporation for the rest of the months were derived in a similar manner.

The Above Cochiti and the Rio Chama FLO-2D models do not use the evaporation component.

Table J-7. Average Hourly Evaporation/ET for 4 MRG ET Towers for May	
Hour	**Percent of Daily ET**
12 – 1 am	1.0
1 – 2 am	0.0
2 – 3 am	0.0
3 – 4 am	0.0
4 – 5 am	0.0
5 – 6 am	0.0
6 – 7 am	0.0
7 – 8 am	2.0
8 – 9 am	5.0
10 – 11 am	6.0
11 – 12 pm	8.0
12 – 1 pm	10.0
1 – 2 pm	11.0
2 – 3 pm	11.0
3 – 4 pm	11.0
4 – 5 pm	10.0
5 – 6 pm	8.0
6 – 7 pm	7.0
7 – 8 pm	5.0
8 – 9 pm	2.0
9 – 10 pm	1.0
10 – 11 pm	1.0
11 – 12 am	1.0

2.3 Irrigation Diversion Return Flows

A modification to the FLO-2D model was made to simplify the simulation of diversions and return flows to the model. Previously, diversions were made by creating a tributary or diversion channel and assigning a hydraulic structure to the diversion channel to control the flow. The diversion channel also had to have an outflow node to discharge flow from the grid system. The model was modified such that inflow hydrographs to the channel could be assigned as either inflow or outflow hydrographs. A new variable was created to identify whether the hydrograph is an inflow to or outflow from the channel. In this way, simple diversions can be structured anywhere in the channel. No diversion structure or tributary channel is necessary. An outflow hydrograph can be created with as few as two or three hydrograph pairs if a constant flow is required. The diversion outflow hydrograph is limited to the flow in the channel such that if a diversion of 500 cfs is specified and there is only 300 cfs in the river channel, the diversion will be 300 cfs and the flow in the river channel will be set to zero.

In the existing model, irrigation diversions are specified for Angostura, Isleta and San Acacia diversion dams. There is also a diversion from Cochiti Dam that is not included in the Cochiti gage data. Based on collaboration with the Middle Rio Grande Conservancy District (MRGCD), return flow locations were identified. For the replication of historic flow events, the Angostura and Isleta Diversion return flows can be estimated as follows (**Table J-8)**:

Table J-8. MRG FLO-2D Model Diversions and Return Flows

Diversion or Return Flow	Diversion or Return	Approximate Discharge (cfs)	Approximate Location (grid element)
Cochiti Diversion	Diversion	200[1]	60
UCRDR	Return	50	2290
ATRDR	Return	50	8972
SANWW	Return	30	1837
ARSDR	Return	70	9000
CENWW	Return	75% of Angostura Diversion[2]	4883
LPIDR	Return	50	16447
PERWW	Return	25	15785
UN7DR	Return	50% of Isleta Diversion	23209
LSJDR	Return	40% Isleta Diversion	22227
Angostura Diversion	Diversion	Variable	1198
Isleta Diversion	Diversion	Variable	9334
LFCC Diversion	Diversion	Variable	23762
Albuquerque Diversion	Diversion	Variable	2349

[1]Cochiti Diversion was assumed to be a constant 200 cfs with an 80% return flow. This 160 cfs is added to the Angostura Diversion for computing the return flow in the Central Avenue Waste Way.
[2]CENWW is assumed to be 75% of the total Angostura Diversion plus the 160 cfs by-pass from Cochiti Diversion.

There are a number of small irrigation return flows that combined may total additional 50 to 100 cfs that are not accounted for in the model. In the FLO-2D simulations supporting the Review (for the 40-year URGWOM planning model data), these returns are consolidated within reaches. The diversion and return flow discharge data is provided by the URGWOM planning team for the various 40-year operation model alternatives. In addition, a diversion for the Albuquerque drinking water project has been added to the model. **Table J-9** through **Table J-11** shows diversions and returns used in the FLO-2D simulations supporting the Review.

Table J-9. MRG FLO-2D Model Diversions and Return Flows			
Type	**Name**	**FLO-2D SIM. Lag Time (days)**	**FLO2D Grid Element #**
Inflows:	Cochiti	0	60
	Galisteo	1	538
	Below Cochiti	1	524
	Below Angostura Diversion	2	1180
	Jemez	3	1265
	North Floodway Channel	3	2016
	Albuquerque Wastewater	3	6953
	South Diversion/Tijeras Arroyo	3	7164
	64% bifurcation return below Isleta	4	15692
	36% bifurcation return below Isleta	4	16447
	Rio Puerco	4	22227
	Unit 7 drain below Bernardo	4	23209
	LFCC below San Acacia Diversion	4	24923
Diversions:	Angostura	2	1198
	City of Albuquerque	3	2349
	Isleta	4	9334
	San Acacia and LFCC	4	23762

Table J-10. Above Cochiti FLO-2D Model InFLOWS			
Type	**Name**	**FLO-2D SIM. Lag Time (days)**	**FLO2D Grid Element #**
Inflows:	Confluence to Otowi	0	3
	Embudo to Otowi Local Inflow	0	1128
	Otowi to Cochiti Local Inflow	0	3149

Table J-11. Rio Chama FLO-2D Model InFLOWS & Diversions			
Type	**Name**	**FLO-2D SIM. Lag Time (days)**	**Grid Element #**
Inflows:	Abiquiu	0	239
	Abiquiu to Chamita Local Inflow	0	11864
Diversions:	Blw Abiquiu Diversions	0	2568
	Abv Confluence Diversions	0	11076

Table J-11. Rio Chama FLO-2D Model InFLOWS & Diversions			
Type	Name	FLO-2D SIM. Lag Time (days)	Grid Element #
	Blw Confluence Diversions	0	13026
	Blw Chamita Diversions	0	14407

2.3.1 Depth Variable Roughness

The Middle Rio Grande has significant variability in bed form roughness from lower regime to upper regime sediment transport as the flow approaches bankfull discharge. Upper regime plane bed can occur at a location for one discharge and not occur at a later time at the same location and same discharge. If the flow regime transitions from dunes to upper regime plane bed, the hydraulic roughness can decrease by as much as 50%. To simulate this effect and improve the timing of floodwave progression through the system, a depth variable roughness component was added to the model. It can be assigned on a reach basis. The basic equation is for the channel element roughness n_d as function of flow depth is:

$$n_d = n_b\, r_c\, e^{-(r2\ depth/dmax)}$$

where:

n_b = bankfull discharge roughness
depth = flow depth
dmax = bankfull flow depth
r2 = roughness adjustment coefficient prescribe by the user (0. to 1.2)
$r_c = 1./e^{-r2}$

This equation provides that the variable depth channel roughness is equal to the bankfull roughness at bankfull discharge. If the user assigns a roughness adjustment coefficient value (r2 = 0 to 1.2) for a given reach, the roughness will increase with a decrease in flow depth; the higher the coefficient, the greater that the increase in roughness.

This roughness adjustment will slow the progression of the floodwave advancing down the channel by increasing the roughness for less than bankfull discharge. The roughness set for bankfull discharge will not be affected. For example, if the depth is 20% of the bankfull discharge and the roughness adjustment coefficient is set to 0.444, the hydraulic roughness of Manning's n-value will be 1.4 times the roughness prescribed for bankfull flow.

2.3.2 Depth Duration

To address issues associated with the Review regarding overbank flooding, a depth duration analysis was coded into the model. An input data parameter is assigned a depth value (typically 0.5 ft.) and the FLO-2D model then computes the duration in hours that this depth is exceeded by the floodplain inundation. This computation is made on a grid element basis and can be plotted graphically with the MAXPLOT processor program. For a given spring runoff hydrograph, the depth duration in hours can be displayed to identify areas of the floodplain where the flood inundation is sufficient to support the riparian ecology in terms of flushing forest litter, nutrient recycling, and cottonwood/willow Bosque regeneration. The depth duration delineation can also support the prediction of slow floodplain velocity habitat for the silvery minnow.

2.3.3 Channel Hydraulics

The analysis of average channel hydraulics was expanded to include thalweg depth, flow velocity, discharge, water surface slope, bed slope, energy slope, bed shear stress, wetted perimeter, top width, hydraulic radius, width-to-depth ratio, and water surface elevation. This output data was written to file for a range of discharges. It can then be analyzed on a grid element basis or over several grid elements in the HYDROG post-processor program. The FLO-2D model was used to simulate steady flow, discharge increments of three to five days to generate the output data files that can be interpolated with the HYDROG program. HYDROG provides the opportunity to select a reach of river and a given discharge to compute the average flow hydraulics in the reach. The average flow hydraulics for a selected discharge are computed by interpolating discharge weighted and reach length weighted average hydraulic conditions. The reach average hydraulics can be computed for any selected discharge ranging from 25 cfs to 10,000 cfs assuming that the selected discharge can be conveyed by the channel at the reach location. This channel hydraulic data can be useful in accessing silvery minnow and other aquatic habitat as function of discharge.

2.3.4 Overbank Flooding

When overbank flooding is initiated in a given grid element, the simulation time (in hours) is written to an output file along with the grid element number, the channel cross section, the thalweg flow depth, velocity, discharge and water surface elevation. The volume of water (in acre-ft) on the floodplain for the whole river system is also reported in the same file. The 40-year URGWOM planning model alternative scenarios provide a wide range of spring flood hydrographs with variable peak discharge magnitude, duration and timing. With floodwave attenuation associated with both channel and overbank storage, the movement of the peak discharge and the corresponding time of initial overbank discharge through the system is highly variable. Overbank discharges can be initiated at different times in different locations for the same Cochiti Dam peak discharge release. The location of initial overbank flooding can be correlated with flood frequency, habitat value and other parameters. This overbank flood information is also provided on a reach basis corresponding with the reaches defined for the Review.

2.3.4.1 Overbank Flow Areal Representation

It is important to clarify the depiction of the predicted overbank flow areas using the FLO-2D model application for the URGWOM hydrographs.

1. The Rio Grande FLO-2D model(s) predict floodplain inundation using a 500 ft grid system. The 500 ft grid element is represented by one elevation and roughness. Topographic variation within the grid element varies, either as mounds or depressions or as a gradual slope of a hillside or bluff. This means that flooding could occur either sooner than predicted by the FLO-2D model or perhaps not at all when predicted by the FLO-2D model for a given grid element if the discharge is approximately bankfull. As was illustrated at the meeting, cattle trampled range lines provide a gully running from the river bank to the levee that could initiate flooding along the levee at an elevation of perhaps 2 ft lower than that predicted by the model.
2. The predicted maximum areas of inundation are summed during model simulation and reported in the SUMMARY.OUT files. These areas are based on the 500 ft grid element representation for the Rio Grande models and 200 ft for the Rio Chama model. Some portion of a flooded grid element can appear on both sides of a levee, or perhaps on the side of a bluff. These grid elements could be assigned area reduction (ARF) values to account for the area outside of the active floodplain. They were not because:

   - An effort was made to balance the number of grid elements with portions inside and outside the levee.
   - This detailed task was not a priority or deemed necessary for the magnitude of the system being modeled.

3. The overall accuracy of the entire area of inundation for a given URGWOM hydrograph is not compromised by this lack of detail.
4. In post processing of FLO-2D results the creation of contours to depict overbank flooding can be based on either grid element flow depths or flow depths that are assigned to every DTM point. The flow depth contours that have been created are based on the grid element resolution.
   - Any contour generating program (e.g. surface modeling program) has a certain level of resolution in creating contour plots. Based on parameters such as line weight, smoothing, number of vertices, algorithm, etc., the contour lines can vary their representation of the flood area or topography. Common hurdles associated with contour line representation are crossing features, crossing contours lines, and extending outside the represented area. In some of the more advanced surface modeling programs breaklines are often used to control contour line creation. MAPPER has a simple contour routine that has to work within the constraints imposed by MapObjects. Mapper does not have breakline capabilities thus; the generated contours lines of flooding that are created as shape files will misrepresent some of the flooded areas. These contour lines will cross the levee in places and perhaps overlay areas with steep slopes.

It is important to recognize that the depiction of the flooded areas with shaded contours and shape files deviates from the FLO-2D computed flood areas. The individual shape polygons are only a general representation of the computed flood areas predicted by the model. The shape polygon areas will not add up to the computed FLO-2D maximum areas of inundation. Any adjustment of the contours or shape polygon could result in a further deviation from computed maximum flooded areas that are predicted as function of the discharge magnitude and duration and the channel geometry and flow hydraulics.

It is also important to realize that the application of the FLO-2D model and MAPPER programs have been consistent for all the URGWOM hydrographs. The same data base was used for every FLO-2D simulation. The contour plotting was automated in MAPPER and the same contour smoothing and resolution parameters were applied for the generation of every shape file. Although the shape polygon images may not “neatly overlay” other spatial data layers and images available in the study reach, the size and shape of the polygons have been created uniformly without additional adjustment and therefore can be used in a comparative study of URGWOM alternative hydrographs.

2.4 Summary Results – FLO-2D Simulations Supporting the Review

The results of the FLO-2D modeling supporting the Review are summarized in spreadsheets. Qualitative depictions of potential overbank inundation for a given FLO-2D simulation is also provided for in graphic shapefiles. The attributes that are included in the shapefiles are discussed in the following paragraph.

The original flood depth shapefile for a specific FLO-2D simulation is created using the MAPPER post-processing program internal to FLO-2D. In Mapper, a representative contouring interval has been selected and consistently used for all post processing of URGWOM simulations. The resulting shapefile from Mapper is then opened in ArcGIS (ArcMap Ver 8.1) an area field is generated and additional X,Y data is joined to the basic flood depth polygons. The X,Y data that is joined includes the following information; the grid cells which experience flood depth of 0.5 ft and higher for a minimum of 1 hour duration (duration reported as hours), and the maximum floodplain velocity experienced at the grid cell during the simulation (reported as feet per second). There are additional fields included in the attribute tables that count occurrences of, average, and report maximum and minimum grid cell data that falls within a specific flood depth polygon.

Table J-12 through **Table J-32** list the summary spreadsheet results of the FLO-2D simulations for all the reaches modeled with FLO-2D. Also in the tables are the duration of each simulation.

Table J-12. MRG FLO-2D Results

	Base Run Version 2 (BaseRun-11.13.03)							
	Timestamp: Nov 24, 2003 3:52PM MST (on urg3)			Max Wetted Floodplain Area				
Year	Simulation Time	Period	Peak at Cochiti	Reach 10	Reach 12	Reach 13	Reach 14	
	(days)		(cfs)	(acres)	(acres)	(acres)	(acres)	
2003	77	Apr 27 - Jul 12	4370	0.00	3.58	16.78	3919.88	
2005	86	Mar 24 - Jun 17	5617	35.84	378.16	670.48	6402.28	
2007	43	Mar 22 - May 3	4316	0.00	0.00	11.05	4519.88	
2010	43	Mar 22 - May 3	4345	0.00	0.00	11.05	4521.11	
2011	43	Mar 22 - May 3	4355	0.00	0.00	11.05	4518.46	
2017	95	Apr 1 - Jul 4	7386	415.51	1393.32	2471.6	7266.70	
2018	91	Apr 20 - Jul 19	5379	0.00	60.82	163.13	5146.74	
2021	91	Apr 21 - Jul 20	5380	0.00	60.82	163.13	5138.89	
2025	64	Apr 28 - Jun 30	5177	0.00	31.34	120.20	4850.37	
2026	125	Mar 27 - Jul 29	6915	293.25	814.80	898.08	5327.11	
2027	61	Apr 30 - Jun 29	5175	0.00	31.34	120.20	4844.51	
2028	81	Apr 4 - Jun 23	5776	49.48	155.40	232.16	5275.31	
2029	85	Apr 17 - Jul 10	7009	330.86	1315.11	2313.1	6737.43	
2030	86	Mar 23 - Jun 16	5406	0.00	271.52	571.79	6085.23	
2031	126	Mar 11 - Jul 14	7514	1473.94	2152.96	3904.0	5526.50	
2036	81	Apr 4 - Jun 23	5776	49.48	155.40	232.16	5289.64	
2037	46	Mar 14 - Apr 28	3569	0.00	0.00	0.00	2224.59	
2038	81	Apr 10 - Jun 29	7370	411.29	1323.70	2364.2	7033.34	
2039	85	Mar 24 - Jun 16	5761	128.80	486.98	725.18	6425.56	
2041	84	Apr 15 - Jul 7	4365	0.00	0.00	11.05	3544.54	
2042	81	Apr 4 - Jun 23	5776	41.58	141.47	223.24	5285.13	

Table J-13. MRG FLO-2D Results

	Alternative B - Wet (B-Wet)						
	Timestamp: Dec 1, 2003 10:11AM MST (on urg3)			Max Wetted Floodplain Area			
Year	Simulation Time (days)	Period	Peak at Cochiti Gage Outflow(cfs)	Reach 10 (acres)	Reach 12 (acres)	Reach 13 (acres)	Reach 14 (acres)
2003	83	Apr 15 - Jul 6	4164	0.00	0.00	7.21	23.58
2005	94	Mar 25 - Jun 26	6301	185.59	1186.96	2119.15	4281.86
2007	60	Mar 17- May 15	4291	0.00	0.00	11.05	34.52
2010	59	Mar 17- May 14	4291	0.00	0.00	11.05	34.52
2011	60	Mar 17- May 15	4291	0.00	0.00	11.05	45.75
2017	94	Apr 2 - Jul 4	8425	1319.61	2103.14	3947.52	5586.46
2018	70	May 11 - Jul 19	4210	0.00	0.00	5.29	14.14
2021	90	Apr 21 - Jul 19	5167	0.00	95.33	185.21	697.92
2025	62	Apr 29 - Jun 29	4950	0.00	9.55	27.38	56.14
2026	95	Apr 25 - Jul 28	7383	411.29	1217.78	1742.32	1678.10
2027	60	May 1 - Jun 29	3873	0.00	0.00	0.00	0.00
2028	45	May 10 - Jun 23	6287	185.59	522.45	642.39	1176.16
2029	80	Apr 21 - Jul 9	7224	337.75	1306.64	2228.48	3190.50
2030	86	Mar 23 - Jun 16	5346	0.00	422.66	814.89	2566.11
2031	120	Mar 10 - Jul 7	8448	1476.85	2156.63	3922.26	5520.03
2036	45	May 10 - Jun 23	6287	185.59	563.28	726.52	1492.94
2037	41	Mar 15 - Apr 24	3236	0.00	0.00	0.00	0.00
2038	64	Apr 10 - Jun 12	8414	1024.78	1657.87	3009.11	4574.33
2039	85	Mar 24 - Jun 16	5401	0.00	462.38	825.52	2540.31
2041	84	Apr 15- Jul 7	4156	0.00	0.00	5.29	17.68
2042	130	Apr 4 - Aug 11	6287	185.59	654.56	887.10	2094.51

Table J-14. MRG FLO-2D Results

	Alternative D - Normal-Wet						
	Timestamp: Nov 26, 2003 9:49AM MST (on urg3)			Max Wetted Floodplain Area			
Year	Simulation Time (days)	Period	Peak at Cochiti (cfs)	Reach 10 (acres)	Reach 12 (acres)	Reach 13 (acres)	Reach 14 (acres)
2003	86	Apr 14 - Jul 8	4588	0.00	3.82	10.99	17.68
2005	86	Mar 24 - Jun 17	5987	134.54	779.41	1324.62	3854.02
2007	41	Mar 22 - May 1	4324	0.00	0.00	11.05	48.45
2010	43	Mar 21 - May 2	4369	0.00	0.00	11.05	48.45
2011	41	Mar 22 - May 1	4367	0.00	0.00	11.05	48.45
2017	96	Apr 1 - Jul 5	7287	396.11	1428.08	2557.22	5049.00
2018	70	May 11 - Jul 19	4236	0.00	0.00	5.29	14.14
2021	90	Apr 21 - Jul 19	5520	0.00	246.21	383.80	1208.54
2025	64	Apr 28 - Jun 30	5276	0.00	41.93	134.41	221.72
2026	96	Apr 25 - July 29	7262	385.78	1096.12	1528.52	1965.63
2027	51	May 10 - Jun 29	3873	0.00	0.00	0.00	0.00
2028	45	May 10 - Jun 23	5776	30.10	112.37	150.76	321.66
2029	84	Apr 21 - Jul 13	7036	331.94	1313.85	2195.77	3451.59
2030	52	Mar 24 - May 14	5299	0.00	193.39	628.98	2298.96
2031	101	Apr 3 - Jul 12	7525	472.53	1408.40	2644.71	5562.38
2036	45	May 10 - Jun 23	5776	30.10	115.82	226.42	380.70
2037	42	Mar 15 - Apr 25	3236	0.00	0.00	0.00	0.00
2038	70	Apr 9 - Jun 17	7375	411.29	1411.15	2442.83	4318.76
2039	52	Mar 24 - May 14	5299	0.00	193.39	630.61	2304.83
2041	71	Apr 27 - Jul 6	4579	0.00	3.82	22.26	49.14
2042	79	Apr 4 - Jun 1	5282	0.00	63.99	153.63	969.55

Table J-15. MRG FLO-2D Results

	Alternative E						
	Timestamp: Nov 26, 2003 9:49AM MST (on urg3)			Max Wetted Floodplain Area			
Year	Simulation Time (days)	Period	Peak at Cochiti (cfs)	Reach 10 (acres)	Reach 12 (acres)	Reach 13 (acres)	Reach 14 (acres)
2003	85	Apr 14 - Jul 7	4418	0.00	7.19	16.78	45.75
2005	83	Mar 24 - Jun 14	6656	264.55	1408.43	2607.79	4920.22
2007	60	Mar 16 - May 14	4324	0.00	0.00	11.05	48.45
2010	60	Mar 16 - May 14	4369	0.00	0.00	11.05	48.45
2011	58	Mar 17 - May 13	4368	0.00	0.00	11.05	48.45
2017	114	Mar 14 - Jul 5	8755	1768.50	2391.96	4226.20	5669.78
2018	70	May 11 - Jul 19	4110	0.00	0.00	5.29	14.14
2021	92	Apr 20 - Jul 20	5422	0.00	39.91	110.93	370.21
2025	63	Apr 28 - Jun 29	5205	0.00	66.56	165.37	351.45
2026	123	Mar 27 - Jul 27	7590	569.02	1343.79	2122.85	2869.23
2027	112	Apr 30 - Aug 19	3874	0.00	0.00	0.00	7.06
2028	79	Apr 6 - Jun 23	6757	255.50	790.44	986.06	1695.82
2029	81	Apr 21 - Jul 10	7480	415.51	1269.43	1928.12	6482.44
2030	86	Mar 23 - Jun 16	5347	0.00	426.50	815.11	2562.24
2031	121	Mar 10 - Jul 8	9401	2497.39	2689.61	4588.54	6746.90
2036	79	Apr 6 to Jun 23	6756	255.50	786.58	983.92	1683.87
2037	41	Mar 15 - Apr 24	3236	0.00	0.00	0.00	0.00
2038	64	Apr 9 - Jun 11	8346	1071.35	1835.41	3345.26	5057.77
2039	86	Mar 23 - Jun 16	5403	0.00	459.53	823.92	2576.83
2041	85	Apr 14 - Jul 7	4410	0.00	3.58	11.05	36.42
2042	80	Apr 3 - Jun 21	7503	370.22	1134.54	1613.08	2369.61

Table J-16. MRG FLO-2D Results

Year	Alternative I dry Timestamp: Dec 16, 2003 9:28AM MST (on urg3) Simulation Time (days)	Period	Peak at Cochiti (cfs)	Max Wetted Floodplain Area Reach 10 (acres)	Reach 12 (acres)	Reach 13 (acres)	Reach 14 (acres)
2003	85	4/14-7/7	4418	0.00	3.58	16.78	2609.62
2005	90	3/24-6/21	5709	3.57	246.03	627.05	5121.74
2007	60	3/16-5/14	4323	0.00	0.00	11.05	3070.41
2010	60	3/16-5/14	4369	0.00	0.00	11.05	3469.01
2011	53	3/22-5/13	4368	0.00	0.00	11.05	3496.93
2017	113	3/14-7/4	7428	415.51	1374.12	2433.79	6826.22
2018	88	4/23-7/19	5421	0.00	115.58	153.37	4683.38
2021	92	4/20-7/20	5422	0.00	115.58	153.37	4687.87
2025	63	4/28-6/29	5178	0.00	27.14	102.90	3724.77
2026	123	3/27-7/27	6920	306.93	892.02	1142.85	5092.10
2027	61	4/30-6/29	5176	0.00	31.34	125.94	4096.04
2028	79	4/6-6/23	5777	47.31	155.40	351.36	4799.73
2029	82	4/20-7/10	7049	330.86	1270.97	2079.33	5462.82
2030	87	3/22-6/16	5566	0.00	143.92	500.69	5323.39
2031	125	3/10-7/12	7530	471.99	1461.06	2806.74	7794.44
2036	80	4/5-6/23	6273	172.35	277.36	467.93	4856.15
2037	47	3/14-4/29	3236	0.00	0.00	0.00	230.61
2038	82	4/9-6/29	7381	405.55	1273.82	2130.25	5855.14
2039	86	3/23-6/16	5997	128.80	504.92	739.88	6514.75
2041	85	4/14-7/7	4409	0.00	0.00	11.05	3702.22
2042	81	4/3-6/22	5777	49.48	152.94	232.16	5387.11

Table J-17. MRG FLO-2D Results

Year	Simulation Time	Period	Peak at Cochiti	Reach 10	Reach 12	Reach 13	Reach 14
	Alternative I - Normal (I-Normal)						
	Timestamp: Dec 16, 2003 9:28AM MST (on urg3)			**Max Wetted Floodplain Area**			
	(days)		Gage Outflow(cfs)	(acres)	(acres)	(acres)	(acres)
2003	73	April 26-July 7	4418.11	0.00	3.58	16.78	3904.55
2005	90	March 24-June 21	5709.44	35.84	383.62	672.46	6250.86
2007	43	March 22-May 3	4323.34	0.00	0.00	11.05	4452.92
2010	43	March 21-May 2	4368.73	0.00	0.00	11.05	4476.75
2011	42	March 22-May 2	4368.01	0.00	0.00	11.05	4515.41
2017	95	April 1-July 4	7270.07	390.37	1392.37	2469.88	7255.62
2018	70	May 11-July 19	5337.29	0.00	54.91	131.68	4979.60
2021	91	April 21-July 20	5421.94	0.00	60.82	163.13	5141.91
2025	63	April 28-June 29	5177.82	0.00	31.34	120.20	4852.31
2026	96	April 24-July 28	7179.50	352.85	962.32	1190.32	5611.17
2027	51	May 10-June 29	4613.06	0.00	3.58	11.05	3614.99
2028	51	May 4-June 23	5777.00	53.05	155.40	232.16	5142.47
2029	81	April 21-July 10	7048.42	325.12	1306.48	2325.98	6861.27
2030	86	March 23-June 16	5299.00	0.00	193.64	630.61	4910.27
2031	127	March 10-July 14	7527.12	483.47	1457.66	2776.65	7288.33
2036	50	May 5-June 23	6273.00	172.35	288.84	486.04	3890.83
2037	42	March 14-April 24	3236.25	0.00	0.00	0.00	0.00
2038	70	April 9-June 17	7381.34	411.29	1406.09	2447.10	5754.9
2039	86	March 23-June 16	5299.00	0.00	183.94	618.83	4876.03
2041	73	April 26-July 7	4409.51	0.00	3.58	11.05	920.77
2042	67	April 3-June 8	5370.33	0.00	86.49	212.20	3244.85

Table J-18. MRG FLO-2D Results							
	Alternative I - Wet (I-Wet)						
	Timestamp: Dec 16, 2003 9:28AM MST (on urg3)			Max Wetted Floodplain Area			
Year	Simulation Time (days)	Period	Peak at Cochiti (cfs)	Reach 10 (acres)	Reach 12 (acres)	Reach 13 (acres)	Reach 14 (acres)
2003	72	Apr 27 - Jul 7	4418.00	0.00	3.58	16.78	45.75
2005	82	Mar 25 - Jun 14	5709.00	35.84	702.41	1138.87	3190.11
2007	43	Mar 22 - May 3	4323.00	0.00	0.00	11.05	48.45
2010	44	Mar 21 - May 3	4368.00	0.00	0.00	11.05	48.45
2011	43	Mar 22 - May 3	4368.00	0.00	0.00	11.05	48.45
2017	94	Apr 2 - Jul 4	7274.00	390.37	1428.32	2557.74	4884.40
2018	70	May 11 - Jul 19	4110.00	0.00	0.00	5.29	14.14
2021	92	Apr 20 - Jul 20	5421.92	0.00	60.82	163.13	5140.88
2025	63	Apr 28 - Jun 29	5177.88	0.00	31.34	120.20	4851.25
2026	96	Apr 24 - Jul 28	7146.74	328.30	852.13	1006.77	5511.65
2027	51	May 10 - Jun 29	3873.88	0.00	0.00	0.00	1512.77
2028	46	May 9 - Jun 23	5776.00	30.10	106.85	150.98	4901.59
2029	81	Apr 21 - Jul 10	7032.54	313.64	1127.32	1577.76	6231.19
2030	53	Mar 23 - May 14	5299.00	0.00	106.97	384.80	5625.38
2031	122	Mar 10 - Jul 9	7472.99	468.44	1412.43	2655.37	5563.57
2036	46	May 9 - Jun 23	5776.00	30.10	115.90	220.68	374.96
2037	42	Mar 15 - Apr 25	3236.27	0.00	0.00	0.00	0.00
2038	68	Apr 9 - Jun 15	7381.3	405.55	1325.43	2357.77	5815.05
2039	86	Mar 23 - Jun16	5299.00	0.00	193.39	627.94	2305.24
2041	73	Apr 26 - Jul 7	4409.6	0.00	3.58	11.05	36.42
2042	80	Apr 3 - Jun 21	5282.00	0.00	58.25	137.39	911.75

Table J-19. Above Cochiti FLO-2D Results

	Base Run Version 2 (BaseRun-11.13.03) Timestamp: Feb 26, 2004 1:38PM MST (on urg3)			Max Wetted Floodplain Area	Max Wetted Floodplain Area
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 8 (acres)	Reach 9 (acres)
2003	14	5/2/03-5/14/03	4097	16.97	0.00
2005	28	4/10/05-5/7/05	5265	111.83	0.00
2007	17	4/8/07-4/24/07	4385	16.97	0.00
2010	17	4/8/10-4/24/10	4419	16.97	0.00
2017	74	4/14/17-6/26/17	9283	802.26	37.74
2018	43	5/11/18-6/22/18	5060	108.99	0.00
2019	6	5/4/19-5/9/19	3751	6.52	0.00
2021	43	5/11/21-6/22/21	5060	108.99	0.00
2024	6	5/4/19-5/9/19	3751	6.52	0.00
2025	23	5/14/25-6/5/25	4733	73.96	0.00
2026	71	4/26/26-7/5/26	6959	327.63	4.45
2027	17	5/14/27-5/30/27	4733	73.96	0.00
2028	57	4/7/28-6/2/28	6969	327.42	4.45
2029	65	4/22/29-6/25/29	6635	284.67	0.00
2030	28	4/10/30-5/7/30	5263	115.42	0.00
2031	91	4/6/31-7/5/31	8486	724.48	46.46
2032	4	5/5/32-5/8/32	3558	6.52	0.00
2034	6	5/4/34-5/9/34	3731	6.52	0.00
2036	55	4/7/36-5/31/36	6969	330.58	4.45
2037	6	4/10/37-4/15/37	3607	6.52	0.00
2038	54	4/17/38-6/9/38	7286	416.98	13.31
2039	27	4/10/39-5/6/39	5265	111.83	0.00
2041	14	5/2/41-5/15/41	4097	16.97	0.00
2042	54	4/7/42-5/30/42	6969	330.58	4.45

Table J-20. Above Cochiti FLO-2D Results					
	Alternative B - Wet (B-Wet)			Max Wetted Floodplain Area	
	Timestamp: Feb 26, 2004 1:38PM MST (on urg3)				
Year	**Simulation Time (days)**	**Period**	**~ Peak Inflow (cfs)**	**Reach 8 (acres)**	**Reach 9 (acres)**
2003	7	5/3/03-5/9/03	3832	9.81	0.00
2005	26	4/10/05-5/5/05	4997	103.26	0.00
2007	11	4/8/07-4/18/07	4342	13.39	0.00
2010	11	4/8/10-4/18/10	4342	13.39	0.00
2011	11	4/8/11-4/18/11	4342	13.39	0.00
2017	74	4/14/17-6/26/17	8082	410.37	8.83
2018	6	5/16/18-5/21/18	3709	16.97	0.00
2021	15	5/12/21-5/26/21	4795	98.91	0.00
2024	3	5/6/24-5/8/24	3462	6.52	0.00
2025	18	5/18/25-6/4/25	4468	64.01	0.00
2026	64	5/3/26-7/5/26	7313	358.39	4.45
2028	12	5/20/28-5/31/28	5736	209.50	0.00
2029	51	5/4/29-6/23/29	6370	254.71	0.00
2030	7	4/13/30-4/19/30	3895	22.71	0.00
2031	87	4/9/31-7/4/31	8485	710.05	46.46
2036	12	5/20/36-5/31/36	6045	238.87	0.00
2038	50	4/17/38-6/5/38	7021	366.01	8.83
2039	7	4/13/39-4/19/39	3895	22.71	0.00
2041	7	5/3/41-5/9/41	3832	9.81	0.00
2042	50	4/7/42-5/26/42	6384	269.52	0.00

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Table J-21. Above Cochiti FLO-2D Results					
Alternative D - Normal - Wet (D-Nml-Wet) Timestamp: Feb 26, 2004 1:38PM MST (on urg3)				Max Wetted Floodplain Area	
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 8 (acres)	Reach 9 (acres)
2003	40	5/2/03-6/10/03	4273	34.44	0.00
2005	29	4/10/05-5/8/05	5422	129.33	0.00
2007	19	4/8/07-4/26/07	4386	16.97	0.00
2010	19	4/8/10-4/26/10	4420	16.97	0.00
2011	19	4/8/11-4/26/11	4426	16.97	0.00
2017	74	4/14/17-6/24/17	8462	466.71	17.78
2018	30	5/16/18-6/14/18	4077	16.97	0.00
2021	44	5/11/21-6/23/21	5237	108.99	0.00
2022	3	5/17/22-5/19/22	3507	6.52	0.00
2023	3	5/17/23-5/19/23	3507	6.52	0.00
2024	9	5/3/24-5/11/24	3928	9.81	0.00
2025	23	5/13/25-6/4/25	4909	78.11	0.00
2026	64	5/3/26-7/5/64	6981	335.72	4.45
2028	13	5/20/28-6/1/28	6045	241.67	0.00
2029	57	5/4/29-6/29/29	6812	301.88	4.45
2030	7	4/13/30-4/19/30	3895	22.71	0.00
2031	88	4/9/31-7/5/31	8485	710.05	46.46
2036	13	5/20/36-6/1/36	6045	233.67	0.00
2038	51	4/17/38-6/6/38	7463	427.14	17.78
2039	7	4/13/39-4/19/39	3895	22.71	0.00
2041	40	5/2/41-6/10/41	4273	34.44	0.00
2042	50	4/7/42-5/26/42	5923	227.40	0.00

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Table J-22. Above Cochiti FLO-2D Results

Alternative E (E-All)				Max Wetted Floodplain Area	
Timestamp: Mar 1, 2004 9:42AM MST (on urg3)					
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 8 (acres)	Reach 9 (acres)
2003	13	May 2 - May 14	4097	16.97	0.00
2005	27	April 10 - May 6	5265	111.83	0.00
2007	16	April 8 - April 23	4386	16.97	0.00
2010	16	April 8 - April 23	4418	16.97	0.00
2011	16	April 8 - April 23	4427	16.97	0.00
2017	73	April 14 - June 25	8289	442.42	17.78
2018	5	May 16 - April 20	3703	16.97	0.00
2021	42	May 11 - June 21	5060	108.99	0.00
2024	5	May 4 - May 8	3751	6.52	0.00
2025	22	May 14 - June 4	4733	73.96	0.00
2026	63	May 3 - July 4	6968	331.62	4.45
2028	12	May 20 - May 31	6043	234.70	0.00
2029	52	May 4 - June 24	6635	283.63	0.00
2030	6	May 13 - May 18	3896	22.71	0.00
2031	87	April 9 - July 4	8485	712.42	46.46
2036	12	May 20 - May 31	6043	234.70	0.00
2038	49	April 17 - June 4	7286	421.40	13.31
2039	6	April 13 - April 18	3895	22.71	0.00
2041	13	May 2 - May 14	4097	16.97	0.00
2042	49	April 7 - May 25	6082	238.87	0.00

Table J-23. Above Cochiti FLO-2D Results

Alternative 1 - Dry Ver. 2 (I-Dry) Timestamp: Mar 1,2004 9:42AM MST (on urg3)				Max Wetted Floodplain Area	
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 8 (acres)	Reach 9 (acres)
2003	14	5/2/03-5/15/03	4097	16.97	0.00
2005	28	4/10/05-5/7/05	5265	111.83	
2007	17	4/8/07-4/24/07	4385	16.97	0.00
2010	17	4/8/10-4/24/10	4419	16.97	0.00
2011	17	4/8/11-4/24/11	4427	16.97	0.00
2017	74	4/14/17-6/26/17	9283	810.17	37.74
2018	43	5/11/18-6/22/18	5060	108.99	0.00
2019	6	5/4/19-5/9/19	3751	6.52	0.00
2021	43	5/11/21-6/22/21	5060	108.99	0.00
2024	6	5/4/24-5/9/24	3751	6.52	0.00
2025	23	5/14/25-6/5/25	4733	73.96	0.00
2026	71	4/26/26-7/5/26	6960	330.58	4.45
2027	17	5/14/27-5/30/27	4733	73.96	0.00
2028	44	4/20/28-6/2/28	6969	328.51	4.45
2029	64	4/23/29-6/25/29	6635	286.42	0.00
2030	25	4/13/30-5/7/30	4603	73.96	0.00
2031	89	4/8/31-7/5/31	8486	724.48	46.46
2032	4	5/6/32-5/9/32	3690	6.52	0.00
2034	5	5/5/34-5/9/34	3725	6.52	0.00
2036	55	4/8/36-6/1/36	6969	328.51	4.45
2038	54	4/17/38-6/9/38	7286	417.76	13.31
2039	17	4/10/39-4/26/39	5265	115.42	0.00
2041	14	5/2/41-5/15/41	4097	16.97	0.00
2042	55	4/7/42-5/31/42	6969	330.58	4.45

Table J-24. Above Cochiti FLO-2D Results

	Alternative I - Normal (I-Normal)			Max Wetted Floodplain Area	
	Timestamp: Mar 1, 2004 9:42AM MST (on urg3)				
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 8 (acres)	Reach 9 (acres)
2003	14	5/2/03-5/15/03	4097	16.97	0.00
2005	28	4/10/05-5/7/05	5265	111.83	0.00
2007	17	4/8/07-4/24/07	4385	16.97	0.00
2010	17	4/8/10-4/24/10	4419	16.97	0.00
2011	17	4/8/11-4/24/11	4427	16.97	0.00
2017	74	4/14/17-6/26/17	8289	442.42	17.78
2018	41	5/13/18-6/22/18	5023	108.99	0.00
2019	4	5/23/19-5/26/19	3618	6.52	0.00
2021	43	5/11/21-6/22/21	5060	108.99	0.00
2024	6	5/4/24-5/9/24	3751	6.52	0.00
2025	23	5/14/25-6/5/25	4733	73.96	0.00
2026	64	5/3/26-7/5/26	6969	336.32	4.45
2027	10	5/24/27-6/2/27	4086	22.71	0.00
2028	24	5/10/28-6/2/28	6969	324.84	4.45
2029	55	5/2/29-6/25/29	6635	286.42	0.00
2030	7	4/13/30-4/19/30	3896	22.71	0.00
2031	88	4/9/31-7/5/31	8486	724.01	46.46
2036	24	5/10/36-6/2/36	6969	324.84	4.45
2038	50	4/17/38-6/5/38	7286	421.40	13.31
2039	7	4/13/39-4/19/39	3896	22.71	0.00
2041	14	5/2/41-5/15/41	4097	16.97	0.00
2042	51	4/7/42-5/27/42	6649	291.95	4.45

1

Table J-25. Above Cochiti FLO-2D Results					
	Alternative I - Wet (I-Wet)			Max Wetted Floodplain Area	
	Timestamp: Mar 1, 2004 9:42AM MST (on urg3)				
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 8 (acres)	Reach 9 (acres)
2003	14	5/2/03-5/15/03	4097	16.97	0.00
2005	28	4/10/05-5/7/05	5265	111.83	0.00
2007	17	4/8/07-4/24/07	4386	16.97	0.00
2010	17	4/8/10-4/24/10	4418	16.97	0.00
2011	17	4/8/11-4/24/11	4428	16.97	0.00
2017	74	4/14/17-6/26/17	4427	16.97	0.00
2018	6	5/16/18-5/21/18	8289	442.42	17.78
2021	43	5/11/21-6/22/21	3703	16.97	0.00
2024	6	5/4/24-5/9/24	5060	108.99	0.00
2025	23	5/14/25-6/5/25	3751	6.52	0.00
2026	64	5/3/26-7/5/26	4733	73.96	0.00
2028	13	5/20/28-6/1/28	6968	334.25	4.45
2029	53	5/4/29-6/25/29	6043	234.70	0.00
2030	7	4/13/30-4/19/30	6635	284.67	0.00
2031	88	4/9/31-7/5/31	3896	22.71	0.00
2036	13	5/20/36-6/1/36	8485	710.16	46.46
2038	50	4/17/38-6/5/38	7286	421.40	13.31
2039	7	4/13/39-4/19/39	3896	22.71	0.00
2041	14	5/2/41-5/15/41	4097	16.97	0.00
2042	50	4/7/42-5/26/42	5304	213.89	0.00

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Table J-26. Rio Chama FLO-2D Results

Base Run Version 2 (BaseRun-11.13.03) Timestamp: Nov 24, 2003 3:52PM MST (on urg3)				Max Wetted Floodplain Area
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2003	86	April 12 - July 6	1800	226
2004	42	April 12 - May 23	1543	32
2005	87	April 8 - June 11	1800	240
2006	35	April 26 - May 30	1800	170
2007	41	March 31 - May 10	1800	210
2008	12	April 26 - May 7	1578	42
2010	41	March 31 - May 10	1800	211
2011	43	March 31 - May 12	1800	205
2012	6	April 29 - May 4	1407	11
2013	13	April 25 - May 7	1548	31
2014	12	April 26 - May 7	1586	42
2016	4	April 11 - May 24	1609	58
2017	52	April 13 - June 3	1800	241
2018	72	April 16 - June 26	1800	255
2019	38	April 23 - May 30	1800	205
2020	35	April 26 - May 30	1800	171
2021	96	April 19 - July 23	1800	255
2022	59	April 23 - June 20	1800	135
2023	61	April 23 - June 22	1800	204
2024	51	April 24 - June 13	1800	204
2025	48	April 24 - June 10	1800	184
2026	74	March 27 - June 8	1800	210
2027	31	April 29 - May 29	1800	185
2028	63	April 4 - June 5	1800	205
2029	86	April 14 - July 8	1800	291
2030	59	April 8 - June 5	1800	238
2031	121	March 9 - July 7	1800	290
2032	34	April 25 - May 28	1610	124
2033	38	April 25 - June 1	1800	200
2034	32	April 25 - May 26	1800	204

Table J-26. Rio Chama FLO-2D Results

	Base Run Version 2 (BaseRun-11.13.03) Timestamp: Nov 24, 2003 3:52PM MST (on urg3)			Max Wetted Floodplain Area
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2035	6	May 12 - May 17	1132	1
2036	58	April 4 - May 31	1800	206
2037	13	April 4 - April 22	1027	1
2038	75	April 14 - June 27	1800	263
2039	45	April 7 - May 21	1800	239
2040	44	April 11 - May 24	1607	56
2041	86	April 12 - July 6	1800	226
2042	57	April 3 - May 29	1800	206

Table J-27. Rio Chama FLO-2D Results

Alternative B - Wet (B-Wet)

Timestamp: Feb 26, 2004 1:38PM MST (on urg3)

Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Max Wetted Floodplain Area Reach 7 (acres)
2003	85	April 12 - July 5	1500	126.25
2004	42	April 12 - May 23	1500	19.67
2005	80	April 8 - June 26	1500	132.64
2006	40	April 26 - June 4	1500	28.82
2007	44	March 31 - May 13	1500	131.82
2008	12	April 26 - May 7	1500	14.53
2010	44	March 31 - May 13	1500	130.01
2011	46	March 31 - May 15	1500	131.28
2012	6	April 29 - May 4	1407	11.69
2013	13	April 25 - May 7	1500	14.53
2014	12	April 26 - May 7	1500	14.01
2016	45	April 11 - May 25	1500	19.67
2017	25	April 13 - May 7	1500	137.91
2018	43	May 30 - July 11	1500	17.27
2019	61	November 1 - December 31	1495	24.82
2020	40	April 26 - June 4	1500	28.82
2021	90	April 19 - July 17	1500	143.05
2022	54	April 23 - June 15	1500	83.40
2023	54	April 23 - June 15	1500	82.56
2024	48	April 24 - June 10	1500	88.27
2025	55	April 24 - June 17	1500	77.47
2026	21	May 22 - June 11	1500	27.13
2028	11	May 24- June 3	1500	19.53
2029	65	May 4 - July 7	1500	140.17
2030	18	May 21 - June 7	1500	16.8
2031	67	May 1 - July 6	1500	172.68
2032	30	November 1 - November 30	1393	11.48
2033	7	December 16 - December 22	1120	0
2034	30	November 1 - November 30	1211	2.78
2036	12	May 23 - June 3	1500	22.17

Table J-27. Rio Chama FLO-2D Results

Year	Alternative B - Wet (B-Wet) Timestamp: Feb 26, 2004 1:38PM MST (on urg3) Simulation Time (days)	Period	~ Peak Inflow (cfs)	Max Wetted Floodplain Area Reach 7 (acres)
2038	44	April 14 - May 27	1500	150.63
2039	12	May 22 - June 2	1500	16.8
2040	44	April 11 - May 24	1500	19.67
2041	85	April 12 - July 5	1500	124.08
2042	49	April 4 - May 22	1500	42.05

Table J-28. Rio Chama FLO-2D Results				
	Alternative D - Normal-Wet (D-Nml-Wet)			Max Wetted Floodplain Area
	Timestamp: Feb 26, 2004 1:38PM MST (on urg3)			
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2003	86	April 12 - July 6	2000	305
2004	42	April 12 - May 23	1543	32
2005	50	April 8 - May 27	2000	315
2006	35	April 26 - June 30	2000	250
2007	41	March 31 - May 10	2000	270
2008	12	April 26 - May 7	1580	42
2010	41	March 31 - May 10	2000	271
2011	39	March 31 - May 8	2000	273
2012	6	April 29 - May 4	1408	12
2013	13	April 25 - May 7	1548	31
2014	12	April 26 - May 7	1580	42
2016	44	April 11 - May 24	1609	58
2017	30	April 13 - May 12	2000	320
2018	42	May 30 - July 10	2000	208
2019	61	November 1 - December 31	1425	15
2020	30	April 26 - May 25	1992	243
2021	83	April 19 - July 10	2000	343
2022	54	April 23 - June 15	2000	276
2023	54	April 23 - June 15	2000	276
2024	48	April 24 - June 10	2000	275
2025	43	April 24 - June 5	2000	268
2026	27	May 24 - June 19	2000	218
2028	12	May 23 - June 3	1902	182
2029	60	May 14 - July 12	2000	328
2030	14	May 23 - June 5	1902	174
2031	67	May 3 - July 8	2000	270
2032	30	November 1 - November 30	1243	4
2034	30	November 1 - November 30	1216	3
2036	11	May 23 - June 2	1902	188
2038	51	April 14 - June 3	2000	356

Table J-28. Rio Chama FLO-2D Results

	Alternative D - Normal-Wet (D-Nml-Wet) Timestamp: Feb 26, 2004 1:38PM MST (on urg3)			Max Wetted Floodplain Area
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2039	7	May 26 - June 1	1517	19
2040	44	April 11 - May 24	1610	49
2041	85	April 12 - July 5	2000	306
2042	48	April 4 - May 21	2000	273

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Table J-29. Rio Chama FLO-2D Results

	Alternative E - All (E-All)			Max Wetted Floodplain Area
	Timestamp: Mar 1, 2004 9:42AM MST (on urg3)			
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2003	86	April 12 - July 6	1800	227
2004	42	April 12 - May 23	1543	32
2005	62	April 8 - June 8	1800	240
2006	35	April 26 - May 30	1800	171
2007	41	March 31 - May 10	1800	210
2008	12	April 26 - May 7	1578	41
2010	41	March 31 - May 10	1800	209
2011	43	March 31 - May 12	1800	206
2012	6	April 29 - May 4	1407	11
2013	13	April 25 - May 7	1548	31
2014	12	April 26 - May 7	1585	44
2016	44	April 11 - May 24	1609	57
2017	25	April 13 - May 7	1800	244
2018 Summer	22	May 29 - June 19	1800	112
2018 Fall	61	November 1 - December 31	1619	73
2019	61	November 1 - December 31	1418	15
2020	35	April 26 - May 30	1800	172
2021	96	April 19 - July 23	1800	256
2022	61	April 23 - June 22	1800	201
2023	61	April 23 - June 22	1800	201
2024	51	April 24 - June 13	1800	204
2025	48	April 24 - June 10	1800	184
2026 Summer	27	May 24 - June 19	1800	124
2026 Fall	61	November 1 - December 31	1800	114
2027	60	November 1 - December 30	1378	10
2028 Summer	12	May 23 - June 3	1800	111
2028 Fall	61	November 1 - December 31	1775	110
2029 Summer	56	May 14 - July 8	1800	246
2029 Fall	60	November 2 - December 31	1374	10
2030 Summer	15	May 22 - June 5	1800	108

Table J-29. Rio Chama FLO-2D Results

Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Max Wetted Floodplain Area Reach 7 (acres)
	Alternative E - All (E-All) Timestamp: Mar 1, 2004 9:42AM MST (on urg3)			
2030 Fall	60	November 1 - December 30	1425	16
2031 Summer	66	May 3 - July 7	1800	197
2031 Fall	61	November 1 - December 31	1726	89
2032	60	November 1 - December 30	1255	5
2033	8	December 15 - December 22	1132	0
2034	30	November 1 - November 30	1227	4
2036 Summer	11	May 23 - June 2	1800	111
2036 Fall	60	November 1 - December 30	1762	108
2038	45	April 14 - May 28	1800	263
2039 Summer	13	May 21 - June 2	1800	106
2039 Fall	59	November 2 - December 30	1437	17
2040	44	April 11 - May 24	1607	55
2041	86	April 12 - July 6	1800	226
2042 Summer	48	April 4 - May 21	1800	199
2042 Fall	30	November 1 - November 30	1505	33

Table J-30. Rio Chama FLO-2D Results				
	Alternatvie I-Dry Chama (I-Dry)			Max Wetted Floodplain Area
	Timestamp: Mar 1, 2004 9:42AM MST (on urg3)			
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2003	86	April 12 - July 6	1800	227
2004	42	April 12 - May 23	1543	32
2005	75	April 8 - June 21	1800	240
2006	35	April 26 - May 30	1800	170
2007	41	March 31 - May 10	1800	211
2008	12	April 26 - May 7	1578	42
2010	41	March 31 - May 10	1800	209
2011	43	March 31 - May 12	1800	206
2012	6	April 29 - May 4	1407	11
2013	13	April 25 - May 7	1548	31
2014	12	April 26 - May 7	1586	43
2016	44	April 11 - May 24	1609	57
2017	50	April 13 - June 1	1800	241
2018	78	April 23 - July 9	1800	256
2019	31	April 29 - May 29	1800	201
2020	35	April 26 - May 30	1800	170
2021	96	April 19 - July 23	1800	254
2022	59	April 23 - June 20	1800	200
2023	61	April 23 - June 22	1800	201
2024	51	April 24 - June 13	1800	204
2025	48	April 24 - June 10	1800	184
2026	72	March 28 - June 7	1800	211
2027	27	May 4 - May 30	1800	183
2028	54	April 13 - June 5	1800	207
2029	79	April 21 - July 8	1800	291
2030	52	April 15 - June 5	1800	203
2031	91	April 8 - July 7	1800	290
2032	27	May 2 - May 28	1800	182
2033	36	April 27 - June 1	1800	200
2034	26	May 1 - May 26	1800	189

Table J-30. Rio Chama FLO-2D Results

	Alternatvie I-Dry Chama (I-Dry) Timestamp: Mar 1, 2004 9:42AM MST (on urg3)			Max Wetted Floodplain Area
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2035	9	May 12 - May 20	1144	1
2036	57	April 7 - June 2	1800	207
2037	5	April 20 - April 24	1380	32
2038	75	April 14 - June 27	1800	263
2039	45	April 7 - May 21	1800	240
2040	44	April 11 - May 24	1607	55
2041	86	April 12 - July 6	1800	227
2042	62	April 3 - June 3	1800	203

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Table J-31. Rio Chama FLO-2D Results

Alternative I – Normal (I-Normal)

Timestamp: Mar 1, 2004 9:42AM MST (on urg3)

Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2003	86	April 12 - July 6	1800	227
2004	42	April 12 - May 23	1543	32
2005	75	April 8 - June 21	1800	240
2006	35	April 26 - May 30	1800	170
2007	41	March 31 - May 10	1800	211
2008	12	April 26 - May 7	1578	42
2010	41	March 31 - May 10	1800	209
2011	43	March 31 - May 12	1800	206
2012	6	April 29 - May 4	1407	11
2013	13	April 25 - May 7	1548	31
2014	12	April 26 - May 7	1586	43
2016	44	April 11 - May 24	1609	57
2017	31	April 13 - May 13	1800	241
2018	58	May 13 - July 9	1800	233
2019	15	May 19 - June 2	1800	106
2020	49	April 12 - May 30	1800	170
2021	96	April 19 - July 23	1800	253
2022	59	April 23 - June 20	1800	202
2023	61	April 23 - June 22	1800	202
2024	51	April 24 - June 13	1800	204
2025	48	April 24 - June 10	1800	183
2026 Summer	35	May 4 - June 7	1800	152
2026 Fall	30	November 1 - November 30	1381	11
2027	8	May 25 - June 1	1651	99
2028 Summer	33	May 4 - June 5	1800	206
2028 Fall	8	November 10 - November 17	1282	6
2029	67	May 3 - July 8	1800	275
2030	34	May 4 - June 6	1800	115
2031 Summer	80	April 19 - July 7	1800	292
2031 Fall	30	November 1 - November 30	1300	6
2032	7	May 22 - May 28	1500	16

Table J-31. Rio Chama FLO-2D Results

Alternative I – Normal (I-Normal)

Timestamp: Mar 1, 2004 9:42AM MST (on urg3)

Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2033	10	May 25 - June 3	1800	109
2034	9	May 21 - May 29	1800	104
2036 Summer	33	May 6 - June 7	1800	203
2036 Fall	8	November 10 - November 17	1282	6
2038	70	April 14 - June 22	1800	263
2039	29	May 4 - June 1	1800	115
2040	44	April 1 - May 14	1607	55
2041	86	April 12 - July 6	1800	226
2042 Summer	50	April 4 - May 23	1800	199
2042 Fall	8	November 10 - November 17	1292	7

Table J-32. Rio Chama FLO-2D Results

Alternative I-3 Timestamp: Mar 1, 2004 9:42AM MST (on urg3)				Max Wetted Floodplain Area
Year	Simulation Time (days)	Period	~ Peak Inflow (cfs)	Reach 7 (acres)
2003	86	April 12 - July 6	1800	227
2004	42	April 12 - May 23	1543	32
2005	62	April 8 - June 8	1800	240
2006	35	April 26 - May 30	1800	171
2007	41	March 31 - May 10	1800	209
2008	12	April 26 - May 7	1578	42
2010	41	March 31 - May 10	1800	209
2011	43	March 31 - May 12	1800	205
2012	6	April 29 - May 4	1407	11
2013	13	April 25 - May 7	1548	31
2014	12	April 26 - May 7	1585	44
2016	54	April 1 - May 24	1609	57
2017	29	April 13 - May 11	1800	243
2018 Summer	22	May 29 0 June 19	1800	111
2018 Fall	61	November 1 - December 31	1690	74
2019	61	November 1 - December 31	1418	15
2020	35	April 26 - May 30	1800	171
2021	96	April 19 - July 23	1800	254
2022	61	April 23 - June 22	1800	201
2023	61	April 23 - June 22	1800	202
2024	51	April 24 - June 13	1800	204
2025	48	April 24 - June 10	1800	184
2026 Summer	27	May 24 - June 19	1800	124
2026 Fall	61	November 1 - December 31	1800	115
2027	61	November 1 - December 31	1378	10
2028 Summer	12	May 23 - June 3	1800	111
2028 Fall	61	November 1 - December 31	1775	108
2029 Summer	56	May 14 - July 8	1800	246
2029 Fall	60	November 2 - December 31	1374	10
2030 Summer	15	May 22 - June 5	1800	108

Table J-32. Rio Chama FLO-2D Results

	Alternative I-3 Timestamp: Mar 1, 2004 9:42AM MST (on urg3)			Max Wetted Floodplain Area
Year	**Simulation Time (days)**	**Period**	**~ Peak Inflow (cfs)**	**Reach 7 (acres)**
2030 Fall	60	November 1 - December 30	1426	16
2031 Summer	66	May 3 - July 7	1800	197
2031 Fall	61	November 1 - December 31	1726	89
2032	60	November 1 - December 30	1255	5
2033	8	December 15 - December 22	1132	0
2034	60	November 1- December 30	1227	4
2036 Summer	11	May 23 - June 2	1800	111
2036 Fall	60	November 1 - December 30	1762	109
2038	50	April 14 - June 2	1800	263
2039 Summer	10	May 23 - June 1	1652	88
2039 Fall	59	November 2 - December 30	1419	15
2040	44	April 11 - May 24	1607	54
2041	86	April 12 - July 6	1800	227
2042 Summer	47	April 4 - May 20	1800	201
2042 Fall	30	November 1 - November 30	1531	40

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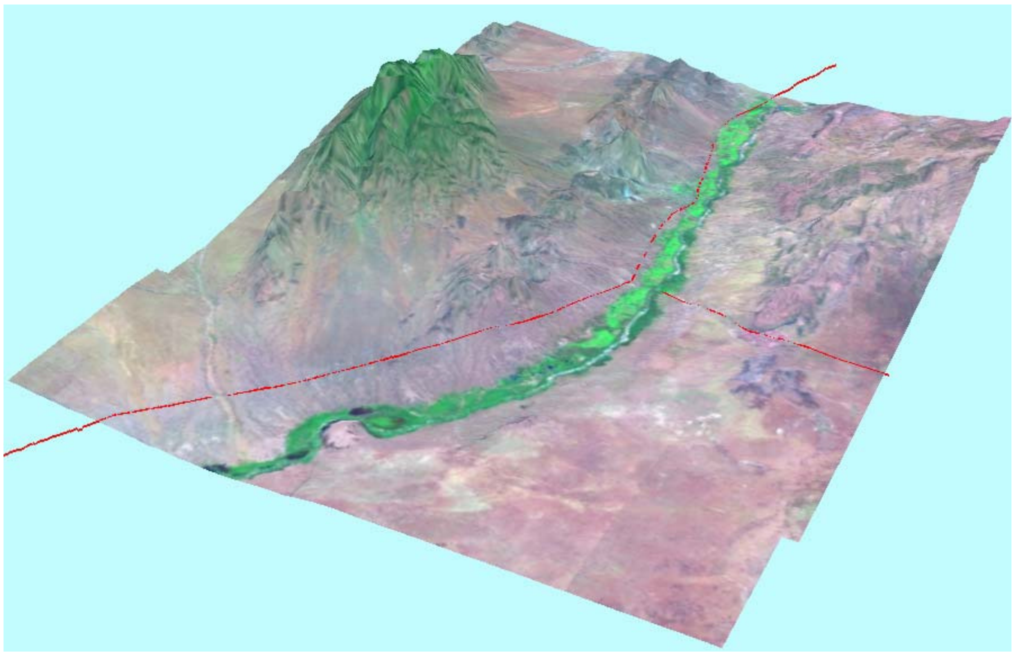
Linked Surface Water and Groundwater Model For Socorro and San Marcial Basins between San Acacia and Elephant Butte Reservoir



By

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Interstate Stream Commission

December 2005

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Linked Surface Water and Groundwater Model for Socorro and San Marcial Basins Between San Acacia and Elephant Butte Reservoir

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ABSTRACT

Surface water and groundwater study of Socorro and San Marcial basins was conducted to develop an understanding of the interaction between surface and subsurface hydrologic systems. Socorro and San Marcial basins are located in central Socorro county, New Mexico. The sixty miles reach of the Rio Grande located between San Acacia and Elephant Butte reservoir experiences high seepage loss that impacts New Mexico's ability to deliver its obligation under the Rio Grande compact to Elephant Butte reservoir. Under Rio Grande compact, New Mexico is obligated to deliver a specified amount of water to Elephant Butte reservoir based on the flow at Otowi gage at northern New Mexico. This flow is required to satisfy portion of the demands above Ft. Quitman and below Elephant Butte Reservoir in New Mexico, Texas and Mexico.

Surface water system in the study area consists of Rio Grande floodway channel, low flow conveyance channel (LFCC) and irrigation and drainage system. The LFCC was constructed during the 1950's to provide an efficient conveyance of water to the reservoir. The LFCC was fully operational for the period from 1959 to 1986. Currently no flow is diverted to the channel and it functions passively as the main drain for the system from San Acacia to Elephant Butte reservoir. Most of the surface water enters the basin at San Acacia is delivered to Elephant Butte reservoir through the Rio Grande floodway and the LFCC. Surface water is consumed by evapotranspiration of crops and riparian vegetations and Evaporation from open waters and wet sand.

Groundwater system consists of the shallow alluvium and Santa Fe group aquifers. The shallow alluvium aquifer thickness varies from few feet along the margin of the basin to about 80 ft at the center of the basin. Thickness of the Santa Fe group aquifer varies from a few feet along the outcrop of the upper Santa Fe to more than 5000 ft at middle of the basin in San Antonio area. Observations of the shallow groundwater system indicated a direct link to the surface water system. Groundwater in the basin is consumed by evapotranspiration of crop and riparian vegetation and municipal and industrial uses. Groundwater levels in the shallow alluvial aquifer oscillate seasonally but do not show a declining tend.

A dynamically linked numerical surface water and groundwater model was developed to better characterize surface water and groundwater relations and to evaluate the use of the LFCC. The model simulates the Rio Grande channel, the LFCC, and the main irrigation canals and drains as well as the alluvial and the Santa Fe group aquifers. The USGS program MODBRANCH is used to represent the surface water/groundwater system. The surface water component is represented by solving the one-dimensional form of the continuity and momentum equations, known as Saint-Venant equation. The groundwater component is dynamically linked to the surface water

component. The physical processes represented in the model are surface water routing, surface water / groundwater interaction, discharge from springs, riparian and crop depletions, groundwater withdrawals and groundwater levels. The model provides groundwater elevation, surface water flow and riparian and crop depletion.

The model was calibrated to surface water flows and groundwater elevations. The model was calibrated against water level data and flow data. Water level data mostly represent measured water levels in the shallow alluvial aquifer. Flow data represent the seepage loss of the Rio Grande and the Gain of the LFCC. Steady state and transient simulations were conducted and the results indicate that the model is adequately represents the hydrologic system.

1.1 INTRODUCTION

During the past five years Interstate stream commission has lunched several data collection studies for the Rio Grande reach from San Acacia to Elephant Butte reservoir. The focus of these studies was to collect hydrologic data to assist in understanding the surface water and groundwater relations. Several seepage investigations were performed to characterize the conveyance efficiency of the surface water system. Improving conveyance efficiency of this reach of the Rio Grande is essential to New Mexico to meet its obligations under the Rio Grande compact. A comprehensive survey of all groundwater monitoring well was conducted to identify well characteristics and develop a water table map for the shallow alluvial aquifer.

Socorro and San Marcial basins are located in central Socorro County, New Mexico as shown in **Figure 1**. Socorro basin is downstream of Albuquerque basin and receives outflow from Albuquerque basin. The study area covers about 453 square miles from San Acacia to the headwaters of Elephant Butte reservoir. Along the Rio Grande valley in the study area altitude ranges from 4730 ft msl (feet mean sea level) at San Acacia to 4420 ft msl at the delta of Elephant Butte Reservoir. About 300 ft drop in altitude through 55 miles length of the Rio Grande. The climate within the basins area is semiarid with an average annual precipitation varies from 6 to 8 inches (NCRS publication).

Most of the study area lies in Socorro county which has a population of about 18,000 people in year 2003 (U. S. Census Bureau, Population Division, April 2004). Population centers in the area are Socorro, San Antonio, Lemitar, and Polvadera. City of Socorro is the largest community with a population of about 8,900 people (BBER, 2000). Groundwater is the principal source for domestic, municipal and industrial uses in the basin. Surface water from the Rio Grande is the main source for irrigated agriculture in the basin. However shallow groundwater is used frequently as a supplemental source for irrigation in the basin during times when there is a shortage of surface water supply.

Under Rio Grande Compact New Mexico is required to deliver its obligations at Elephant Butte reservoir. This reach of the Rio Grande lies just above the headwaters of Elephant Butte reservoir and understanding its hydrologic characteristics are essential for New Mexico to comply with Rio Grande Compact. Therefore, New Mexico Interstate Stream Commission (ISC) has begun a hydrologic and modeling investigations of the San Acacia reach. This report describes hydrologic modeling study of the surface water and groundwater of Socorro and San Marcial basins.

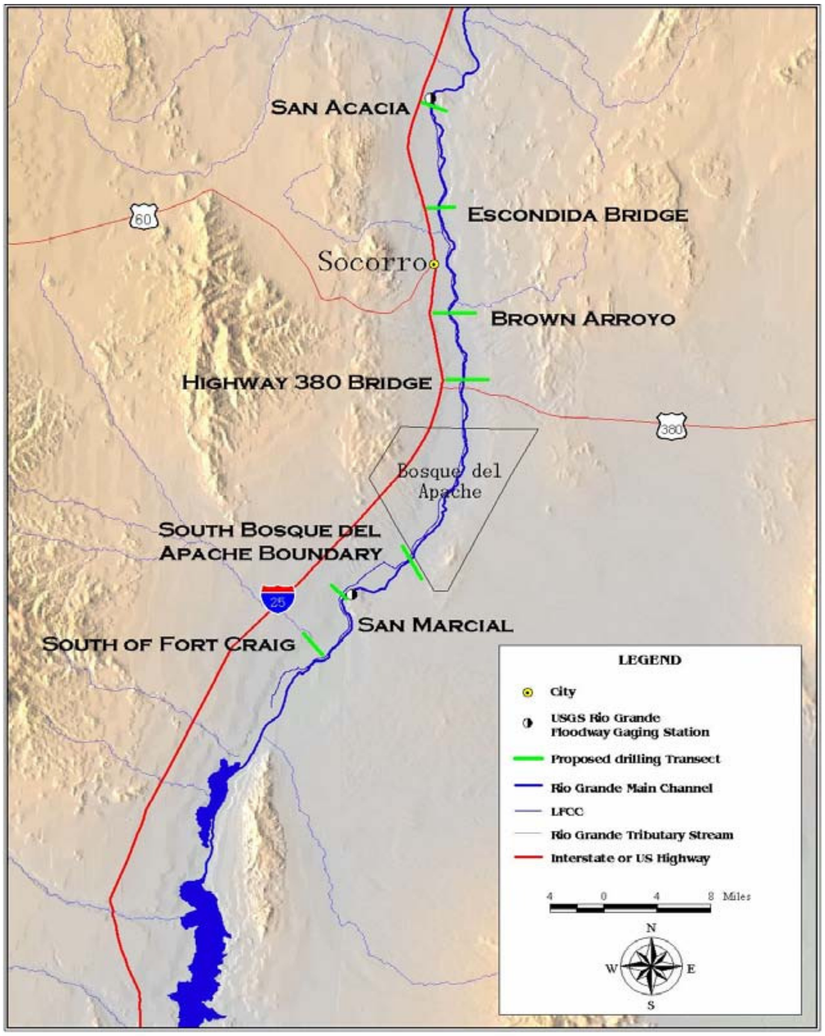

Figure 1. Location Map of Socorro and San Marcial Basins.

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2.0 Purpose and Scope

Understanding surface water and groundwater relations in the San Acacia reach of the Rio Grande is critical for New Mexico to comply with its compact obligations. The purpose of this study is to develop numerical model that describes the interaction between each components of the hydrologic system. The objectives of the surface water and groundwater model are to evaluate surface water conveyance efficiency, investigate different mode of operations of the LFCC, and evaluate impact of restoration projects on river flow.

2.1 Previous Investigations

Several previous studies focused on the geologic formation and structure of the study area. Denny (1940, 1941) described the Quaternary and Tertiary geology of the San Acacia area. Kelley (1952) presented a description of the structural features in Socorro and San Marcial basins. Chapin and Seager (1975) described the development of the Rio Grande rift and Chapin et al. (1978) described the hydrogeologic setting of the Socorro geothermal area.

Allan Sanford (1968) developed a detailed gravity survey map covering part of the Rio Grande depression and adjacent area in central Socorro County, New Mexico. A regional and residual Bouguer anomaly maps were presented and was utilized in the present study for interpretation of the total model thickness.

Anderholm (1983) provided a hydrogeologic description of Socorro and La Jencia basins. Anderholm's report presented a brief description of the surface water and groundwater systems and their interrelation. Anderholm estimated about 2000 acre-feet per year (afy) as mountain front recharge to Socorro basin. In addition, he provided an overall estimate of the water budget for Socorro basin.

Roybal (1989) studied the groundwater resources in Socorro County. The study presented water levels and water quality for most of groundwater wells in Socorro County. The report provided an estimate of mountain front recharge in all County including Socorro and San Marcial basins using a regression equation described in Hearne and Dewey (1988). About 14,000 afy were estimated as mountain front recharge to Socorro and San Marcial basins.

2.2 Acknowledgments

Several people have contributed to the development of this work. Specifically the author acknowledges the valuable discussion with John Hawley and Bruce Allan regarding basin geohydrologic concept. Rob Bowman and his students and Papa Dopulos and Associates were instrumental in data collection. The author thanks Estevan Lopez, Rolf Schmidt Petersen and Kevin Flanigan for their support and technical review of the document.

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3.0 GEOHYDROLOGY OF SOCORRO AND SAN MARCIAL BASINS

The study area extends about 55 miles along the Rio Grande from San Acacia to the headwaters of Elephant Butte reservoir with an average of 8 miles wide, as shown in **Figure 1**. The study area is about 453 square miles lie within the Rio Grande depression and surrounded by Lemitar, Socorro, Magdalena and San Mateo mountains from the west and Lomas De Las Canas upleft, Cerro Colorado and Little San Pascual Mountains from the east. The following sections describe the climatic and geo-hydrologic characteristics of the area.

3.1 Climate

The climate in the basin area is predominantly semi-arid. Precipitation records at selected weather stations indicated that long-term average annual precipitation is 8.0 inches in the valley and about 12 inches in mountainous areas. More than 40 percent of precipitation falls during monsoon months July through September. Average annual temperatures vary from 57 F in the valley to 52 F on the Magdalens.

3.2 Geologic Setting

Understanding the geologic settings in the basin is essential in determining conceptual framework of the system and its hydrologic properties. **Figure 2a** illustrates the surface geology of the Socorro and San Marcial basins. The basin is bounded on north by basin uplift (San Acacia constriction) which separate Socorro basin from the Middle Rio Grande basin. Lemitar, Magdalena, Chupadera Mountains and Socorro peak form the western boundary of the basin. Joyita and Los Pinos uplifts and San Pascual Plateform form most of the eastern boundary, and from the south by San Mateo uplift and San Pascual Plateform.

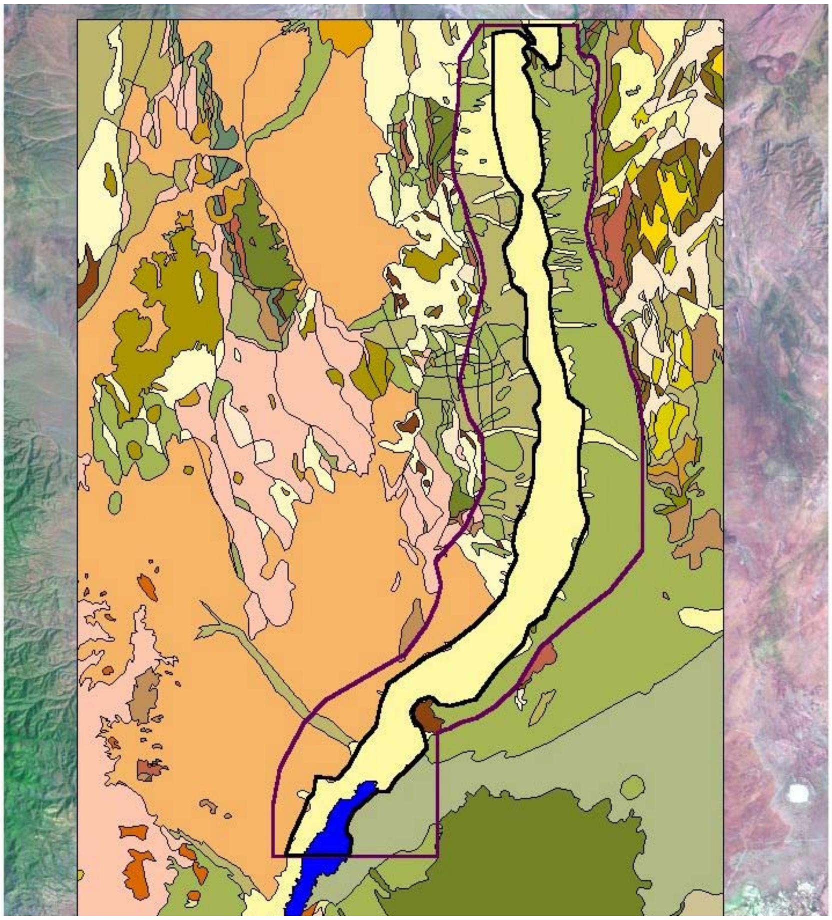


Figure 2a. Surface Geology and Model Outline.

In Socorro peak, Lemitar Mountains, Magdalena and Chupadera mountains volcanic rocks overlie the Precambrian and Pennsylvanian rocks. Alluvial deposits cover the valley of the basins which overlie the Santa Fe group of the Tertiary and Quaternary age. A geologic cross section in Socorro basin is illustrated in **Figure 2b** (Anderholm, 1987). Faults exist on the eastern and western boundaies of the basin that separate Socorro basin from La Jencia (west) and the Jornada Del Muerto (east) basins.

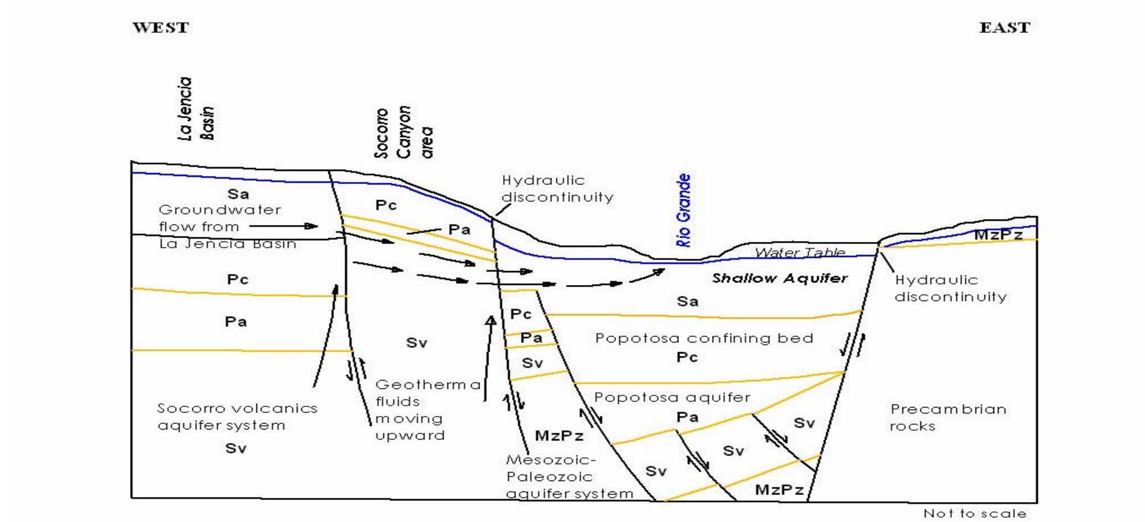


Figure 2b. Geologic X-Section (Anderholm 1987)

The sedimentary fill of the Socorro and San Marcial basins is composed of the Teriary and Quaternary Santa Fe Group and basin fill deposits. The Santa Fe Group thickness is as much as 5000 ft. The alluvium of the inner valley consists of post Santa Fe Group deposits from the most recent deposits. Recent geologic logs indicated that thickness of alluvial deposits varies from 80 to 100 ft.

3.2.1 Surface Water Hydrology

Surface waters enter the basin at San Acacia through the Rio Grande and drain unit 7 west of the Rio Grande (**Figure 3**). The Rio Grande represents the main natural river channel which flows through the basin from San Acacia to Elephant Butte reservoir. Depending on the hydrologic year this reach of the Rio Grande can dry during the summer months. Other ungaged tributaries east and west of the Rio Grande collect runoff during storm events mainly during monsoon season. The total surface water flow enters to the basin is highly variable (**Figure 4)** it can vary from 200,000 afy to more than 2,000,000 afy.

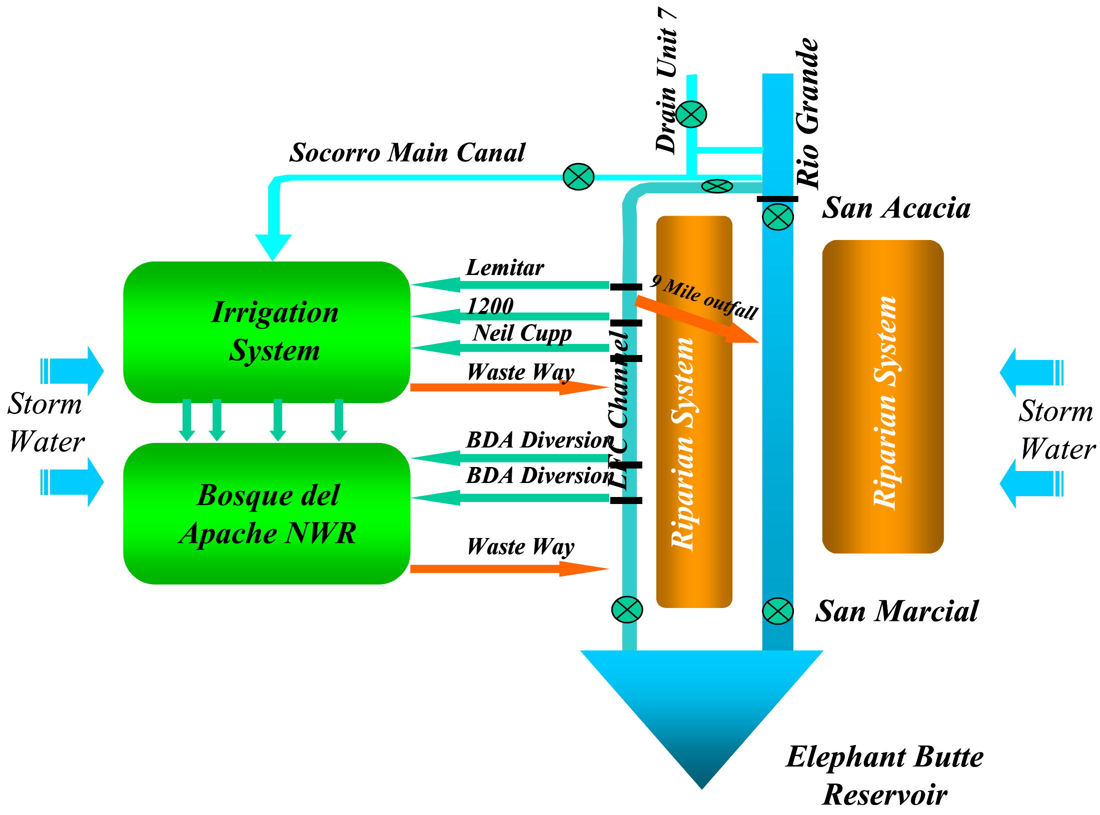


Figure 3: Schematic of the Surface Water System.

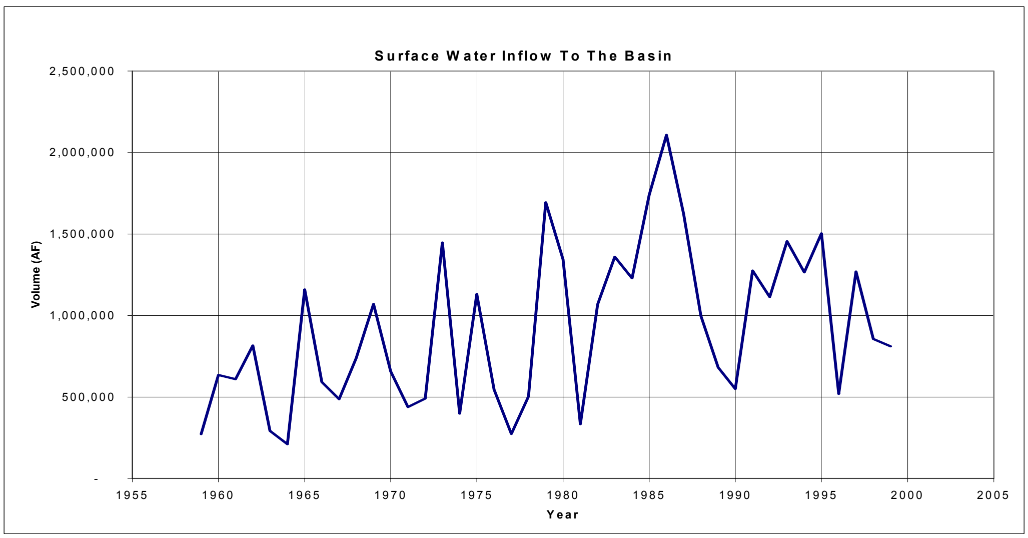


Figure 4. Total Surface Water Inflow.

Another surface water feature of the basin is the Low Flow Conveyance Channel (LFCC), which runs parallel to the river starting from San Acacia to Elephant Butte reservoir. LFCC was constructed during the 1950's as part of the Middle Rio Grande project to improve water conveyance through the basin. The LFCC was designed to be the lowest point in the valley (i.e. its bed elevation is below the river channel by about 10 to 15 ft) and carry a maximum capacity of 2000 cfs. From mid 1950's till 1986 the LFCC was used to convey the Rio Grande water up to its maximum capacity to Elephant Butte reservoir and the river channel was to carry only the additional flows above 2000 cfs. After the high flow years of early 1980's and the spill of the Elephant Butte reservoir the lower end of the LFCC was plugged by sediment and active diversions to the LFCC were discontinued till present. Currently the LFCC is serving as the main drain of the surface water system and at the same time supplies water for irrigated land and for Bosque del Apache National Wild Life Refuge. **Figure 5** shows the annual flow of the LFCC and the Rio Grande floodway at San Marcial, the sum of these two flows represent the total surface water outflow.

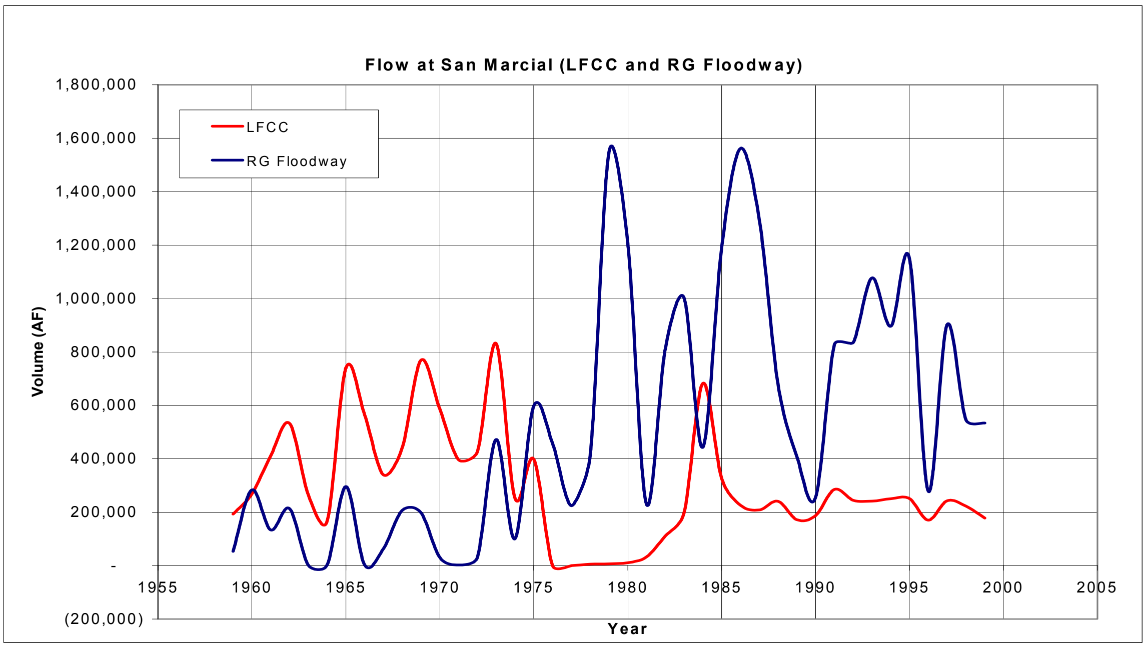


Figure 5. Flow at San Marcial LFCC and Rio Grande Floodway (SW outflow).

Surface water is diverted for irrigation from the Rio Grande at the San Acacia diversion dam. Socorro Main canal is the main irrigation channel (max capacity of about 280 cfs) that distributes water to farms in Socorro basin. Socorro main canal gets its water from direct diversion from the Rio Grande and from drain Unit 7 which collects drainage water of the west side of Bellen division. In addition to Socorro Main canal, the irrigation system consists of laterals, sub-laterals, ditches and drains. Elmondorf drain collects all drainage water from the basin and routed it to the LFCC above San Marcial. All irrigation in Socorro basin occurs west of the Rio Grande, it is reported by MRGCD that about 10,000 to 12,000 acres irrigated annually in Socorro division.

Surface water depletion in the basin is defined as the difference between total surface water inflow and total surface water outflow of the basin. Total surface water inflow is represented by the sum of the following gaging station at San Acacia: Rio Grande Floodway, LFCC, and Socorro Main canal. Total surface water outflow is represented by the sum of the Rio Grande Floodway and the LFCC at San Marcial. **Figure 6** illustrates the cumulative surface water depletion for the period from 1959 to 1999. Analysis indicated that changing LFCC operation resulted to more surface water depletion in the basin. When the LFCC was used to convey water regularly surface water depletion was about 70,000 afy. When using the river channel as the main conveyance and discontinuous the use of the LFCC surface water depletion increased to about 100,000 afy. This increase of depletion is mainly due to increase of evaporation loss from river channel and transpiration loss of riparian vegetation east of the river.

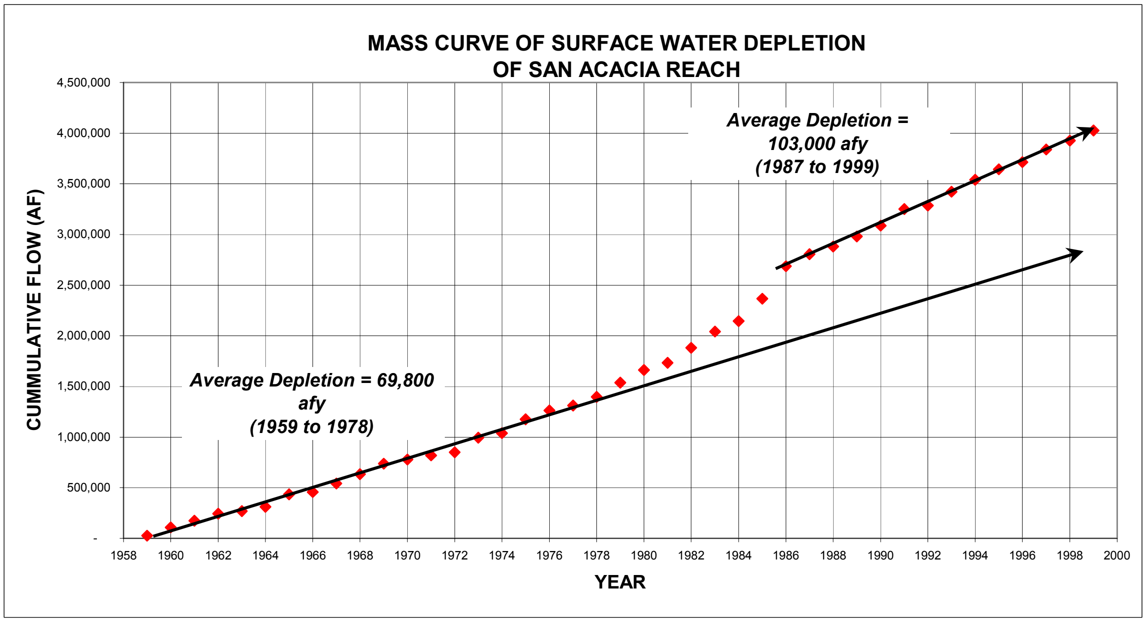


Figure 6. Mass Curve of Surface Water Depletion.

3.2.2 Groundwater Hydrology

The aquifer system in Socorro and San Marcial basins is composed of the Tertiary and Quaternary Santa Fe Group and basin fill alluvial deposits. The shallow alluvial aquifer along the Rio Grande channel represents the most permeable part of the aquifer system while the Santa Fe Group aquifer is orders of magnitude less permeable. Thickness of the alluvial aquifer varies from 10 ft along the edges to about 100 ft along the axis of the Rio Grande. Thickness of the Santa Fe group aquifer varies from couple hundred feet along the edges to about 5000 ft at the thickest part near San Antonio.

Recharge to groundwater occurs through shallow underflow originating from mountains adjacent to the basin (Mountain-Front recharge) and seepage through streambeds (ephemeral streams recharge) during rainfall events. Recharge on the east side of the basin is mostly due to infiltration of runoff derived from precipitation and was estimated at about 1,450 afy (Roybal, 1991) using Hearn and Dewey (1988) approach. Along the west recharge occur along Lemitar Mountains (724 afy), Socorro Peak (2900 afy) and Chupadera Mountains (724 afy) as shown in **Figure 7** (Roybal, 1991).

To understand the general water movement in the shallow aquifer monitoring wells in the study area with depths less than 100 feet was used to develop a water table map (**Figure 8**). In general groundwater moves from east and west to the center of the basin where it discharges to the surface water features. The water table map also indicates a strong north-south hydraulic gradient.

Groundwater is used in the basin for domestic, municipal and Industrial purposes as well as to supplement irrigation use. Most of wells in Socorro and San Marcial basins derive water from the shallow and the top of Santa Fe Group aquifers. Monitoring wells indicate that shallow groundwater levels experience seasonal fluctuations with almost steady water levels as shown in **Figure 9**.

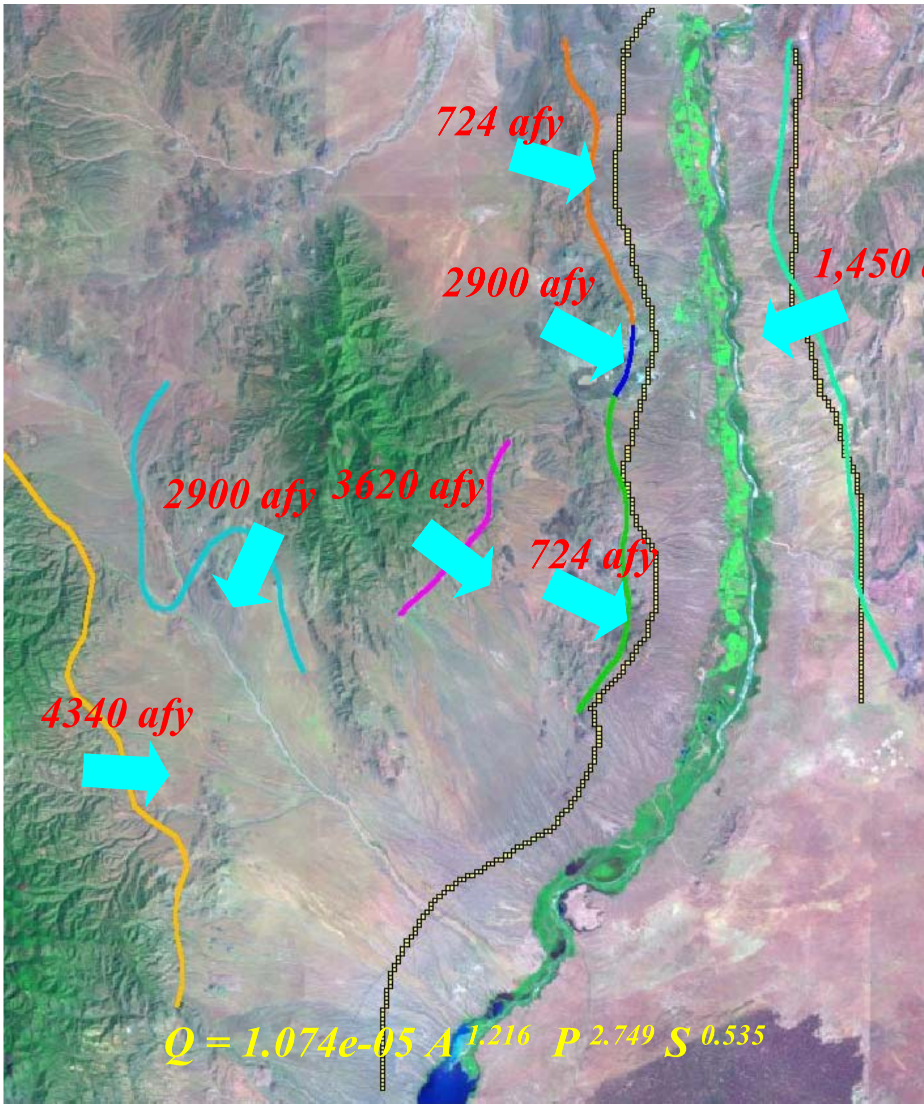


Figure 7. Estimated Mountain Front Recharge (Roybal 1991).

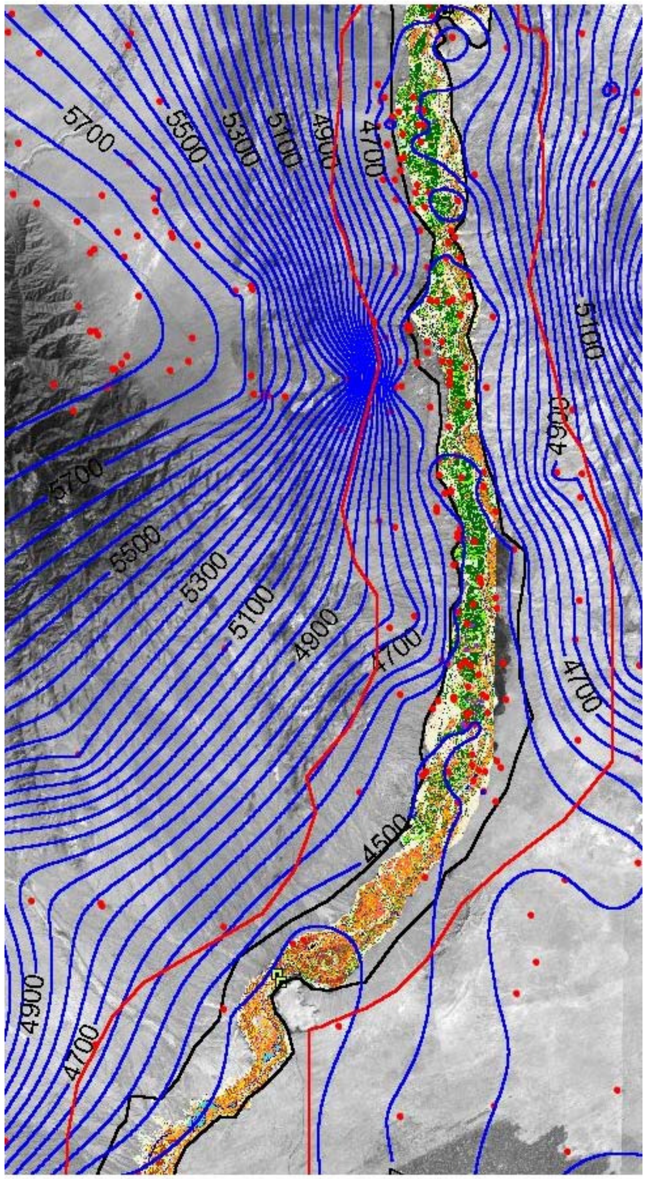


Figure 8. Map of Water Table Using Monitoring Wells.

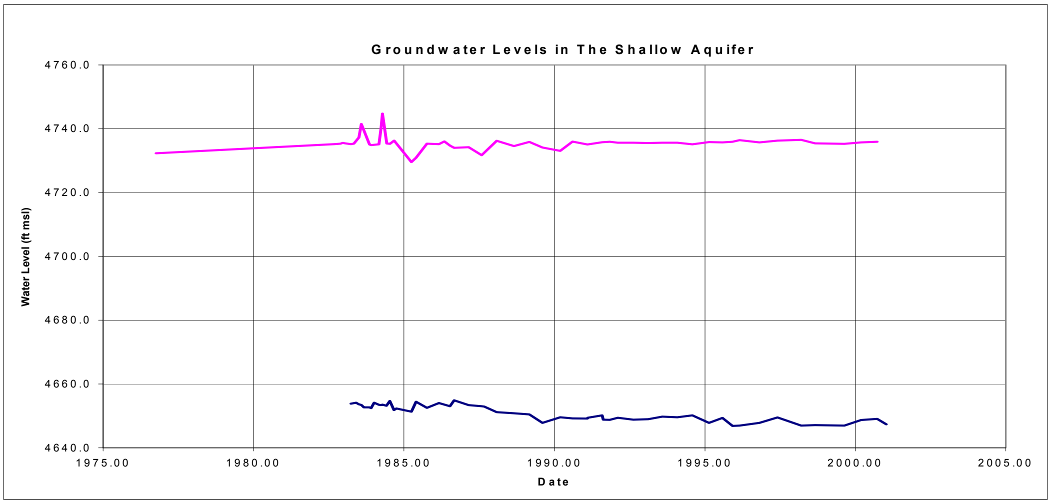


Figure 9. Measured Water Levels at Selected Locations

3.3 Hydrologic Properties

Several aquifer tests were conducted recently by Interstate Stream commission to characterize the hydrologic properties of the shallow aquifer. Two irrigation wells with total depth of about 100 ft were tested and yield a hydraulic conductivity of the shallow aquifer of 100 to 150 ft/day and specific yield of about 0.15. Another well-designed aquifer test was conducted along the HW-380 transect. The shallow aquifer was pumped at a rate of 76 gpm from depth 35 to 50 ft below ground surface. Aquifer response was monitories at depths of 5 to 10 ft bgs, and 75-85 ft bgs as well as the pumped zone (**Figure 10**). The test was analyzed by the ISC staff (Nabil Shafike) and the ISC consultant Papadopulos and Associates. Both analysis estimated aquifer hydraulic conductivity of 60 to 70 ft/day, specific yield of 0.15 and vertical anisotropy between 10:1 and 20:1.

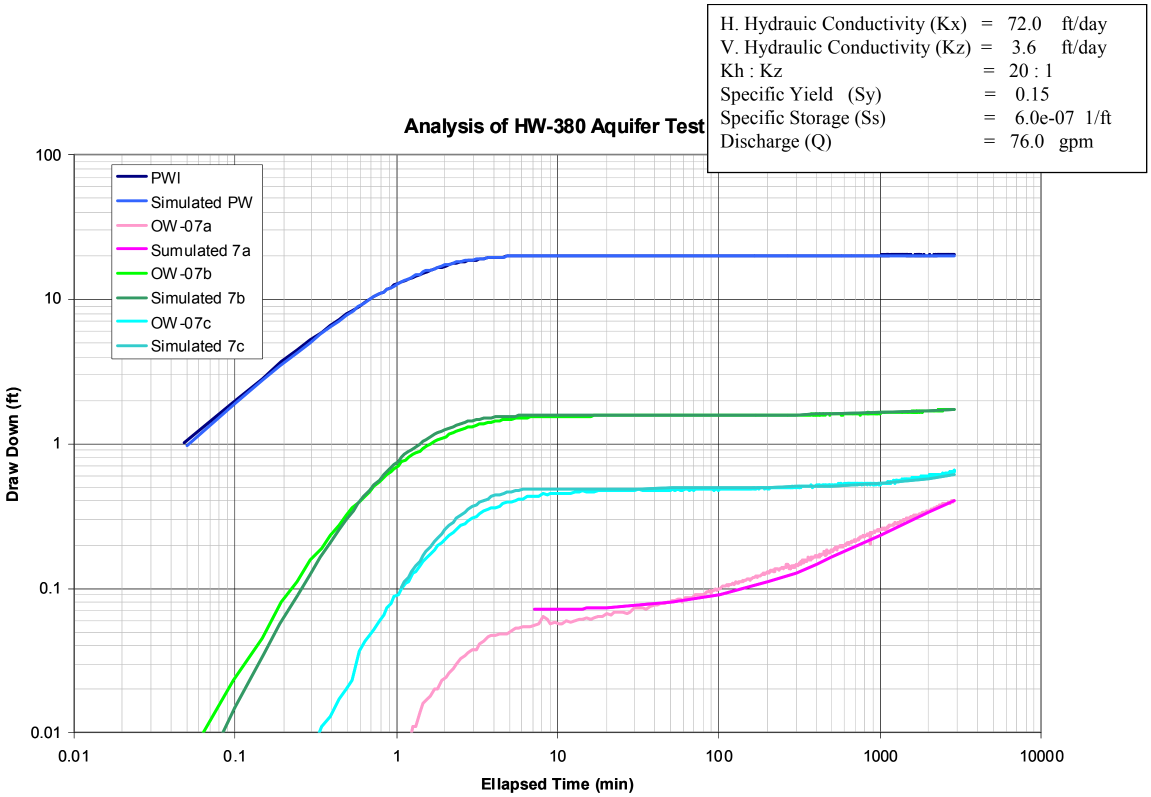


Figure 10. HW-380 Aquifer Test Analysis.

3.4 Basin Water Depletion

Depletion is defined as the amount of water that is lost from the system. Water is depleted in the basin by riparian and crop evapotranspiration, M&I and openwater evaporation. For riparian and crop evapotranspiration and open water evaporation estimates were developed using an average area multiplied by average consumptive use. Municipal and Industrial uses were estimated based on City of Socorro consumption. Average annual basin depletion of about 108,000 af. Riparian ET represents 59 percent of total depletion, crop consumption represents 31 percent, open water evaporation represents about 9 percent, M&I is about 1 percent.

4.0 MODEL DESCRIPTION

General groundwater movement through porous media can be described by combining the continuity and momentum equations of the flow system to yield the general partial differential equation as follow:

$$\frac{\partial}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) - q = S_s \frac{\partial h}{\partial t} \qquad (1)$$

Where:

K_x, K_y, *and* K_z are the hydraulic conductivity along the principal axis x,y and z (LT^{-1});
h, is potentiometric head (L);
S_s is the specific storage (L^{-1}); and
T is time (T).

The surface water flow equation can also be described using the Saint Venant equation, which is the one-dimensional momentum and continuity equations in open channel, and can be written as follows:

$$\frac{1}{gA}\frac{\partial Q}{\partial t} + \frac{2\beta\, Q}{gA^2}\frac{\partial Q}{\partial x} - \frac{\beta\, Q^2}{gA^3}\frac{\partial A}{\partial x} + \frac{\partial Z}{\partial x} + \frac{k}{A^2 R^{4/3}} Q\,|\,Q\,| - \frac{\xi B}{gA} U_a^2 \cos\alpha \;= 0 \qquad (2)$$

$$B\,\frac{\partial Z}{\partial t} + \frac{\partial Q}{\partial x} + q = 0 \qquad (3)$$

Where,

Q is the flow in stream (L^3T^{-1});
A is the cross section area (L2);
Z is the depth of the flow in channel (L); and
B is the channel width (L)

The above system of equations is used to describe the flow movement in the surface water and groundwater systems and the link between the two systems can be described as follows:

$$q = \frac{K'}{b'} B (Z - h) \quad (4)$$

Where,

Q is the flow per unit length (L^2T^{-1});
K` is the vertical hydraulic conductivity of riverbed (LT^{-1}); and
b` is the thickness of the riverbed (L).

The USGS program developed a program that uses the above system of equation called MODBRANCH (USGS, 1997) which couples the groundwater program MODFLOW to the surface water model Branch. This program is used in this study because its ability to accurately represent the interaction between surface water and ground water which is an important aspect of this study.

4.1 Spatial and Temporal Discretization

The model covers an area of about 600 square miles and is discretized horizontally into a 1000 ft by 1000 ft grid as shown in **Figure 11a**. In the vertical dimension the model consists of five layers, layer one represent the shallow alluvial aquifer. Layers 2 through 5 represent the upper, middle and lower Santa Fe group aquifer (**Figure 11b**). Due to the fact that surface water travel faster than groundwater, and to be able to reach stable numerical solution the groundwater computations is done on a daily stress period and the surface water computation is done on a much smaller time step.

4.2 Boundary Conditions

In general model boundary conditions describe how water enters or leaves the aquifer system. These conditions can be specified flow or head-dependent flow boundaries.

4.2.1 Specified Flow Boundaries

Mountain front recharge, municipal pumping and crop deep percolation are represented in the model as specified flow. Most of irrigation canals and distribution system is above the water table therefore canal seepage is also represented as constant flow.

4.2.2 Head-Dependent Flow Boundaries

The Rio Grande, the LFCC and the drains are represented as head dependent boundaries. A prescribed head boundary is used to represent the link between the Middle Rio Grande basin and the Socorro basin; and the groundwater leaving the system at the southern boundary of the model (south of San Marcial). Riparian vegetation is represented by head-dependent flow boundary that allows water to discharge from the aquifer as a function of the depth to water table.

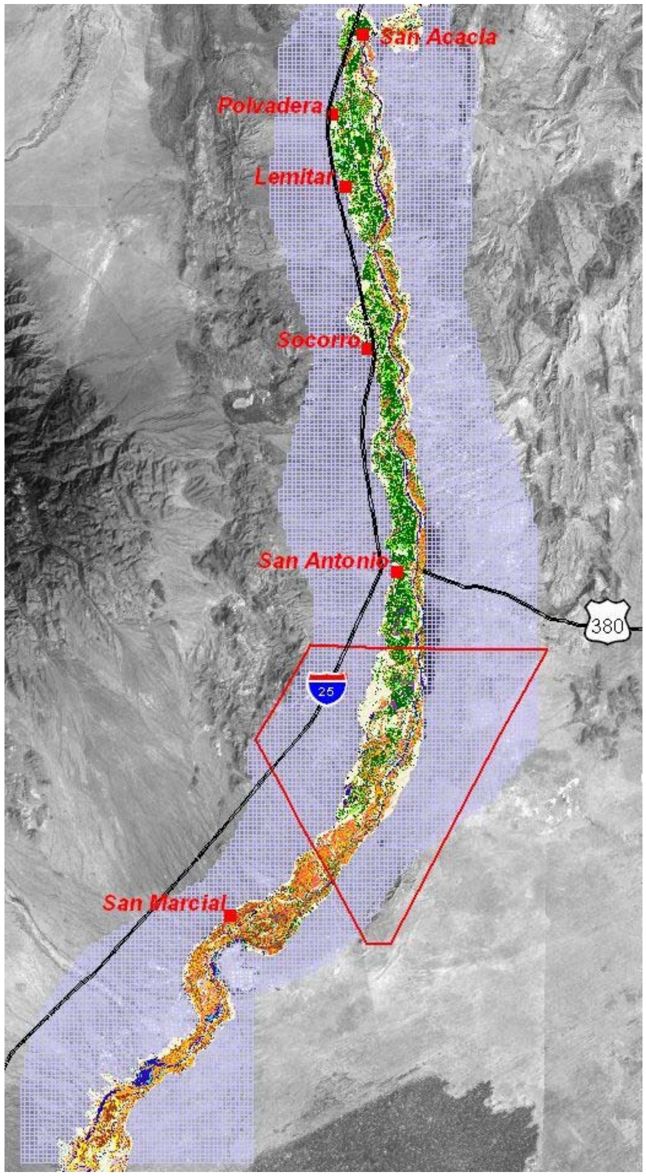
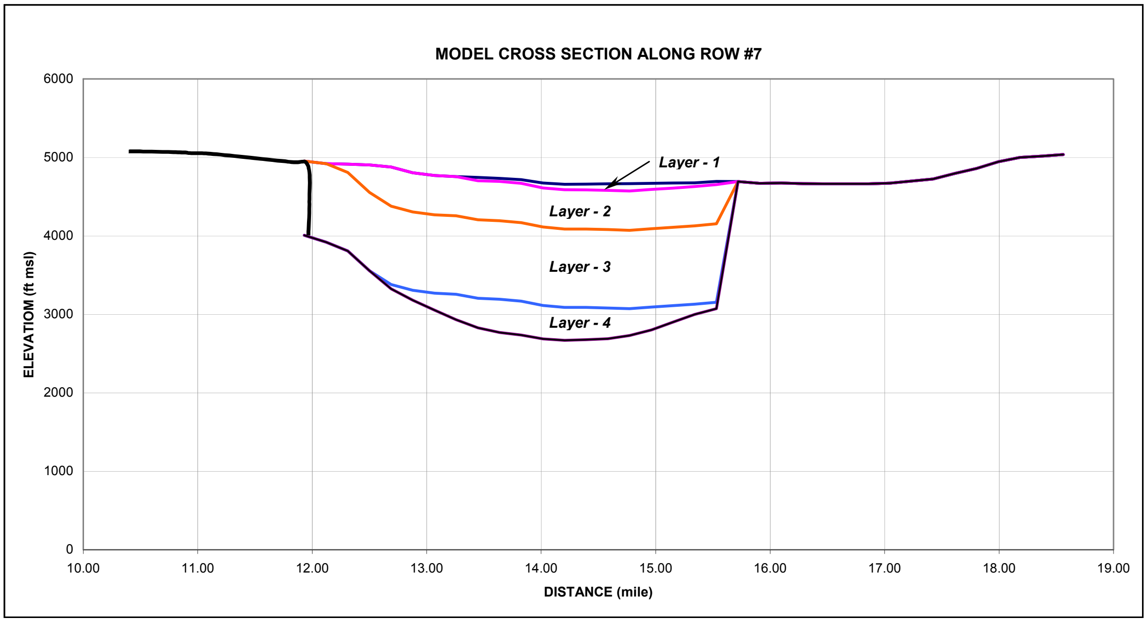
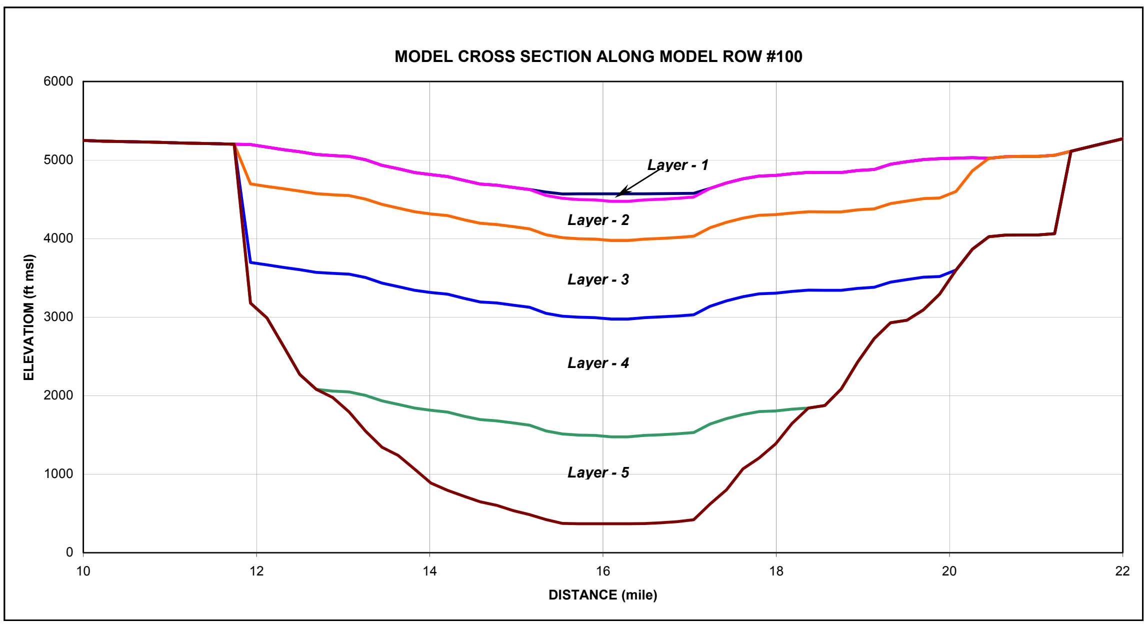


Figure 11a. Active Model Grid



Model X-Section Near San Acacia



Model X-Section Near Socorro

Figure 11b. Model X-Sections

5.0 MODEL CALIBRATION

The model was calibrated using trial and error approach by adjusting aquifer properties and conductance in an effort to minimize the difference between measured and simulated water level and flow data.

5.1 Calibration Targets

The primary calibration targets are water levels measured in wells and piezometers and estimated seepage or gain of surface water system. The calibration is said to be satisfactory if we achieved acceptable match within the reasonable range of aquifer properties.

5.2 Steady State

The calibration process was focused on the shallow aquifer within the valley since all measured water level data is in that area. The model was run for steady state and the horizontal hydraulic conductivity was adjusted. Final calibrated hydraulic conductivities are 100 ft/day for the shallow aquifer, 1 ft/day for the upper Santa Fe Group aquifer and 0.1 ft/day for the deeper Santa Fe aquifer. **Table 1** lists the calibrated aquifer properties. **Figure 12** illustrate the comparison between measured and simulated water levels at observation wells. Results indicated that the root mean square error is about 24 ft. **Figure 13** illustrate the simulated water table that indicates that the water table varies from 4700 ft msl at San Acacia to about 4500 ft msl at San Marcial. The Rio Grande seepage and the LFCC gain was computed and compared to the estimated amount using seepage runs analysis (**Figure 14**). Results indicated that under steady state conditions the river loses about 265 cfs between San Acacia and San Marcial and the LFCC gains about 200 cfs at the same reach (**Figure 15**). These results are consistent with the seepage run analysis conducted during 2000 and 2001.

Table 1. Calibrated Aquifer Properties.

Formation	K_h (Feet/day)	K_h/K_z	Sy
Alluvial Aquifer	100.00	2.00	0.050
Upper Santa Fe	1.00	100.00	0.001
Middle Santa Fe	0.50	100.00	0.001
Lower Santa Fe	0.10	100.00	0.001

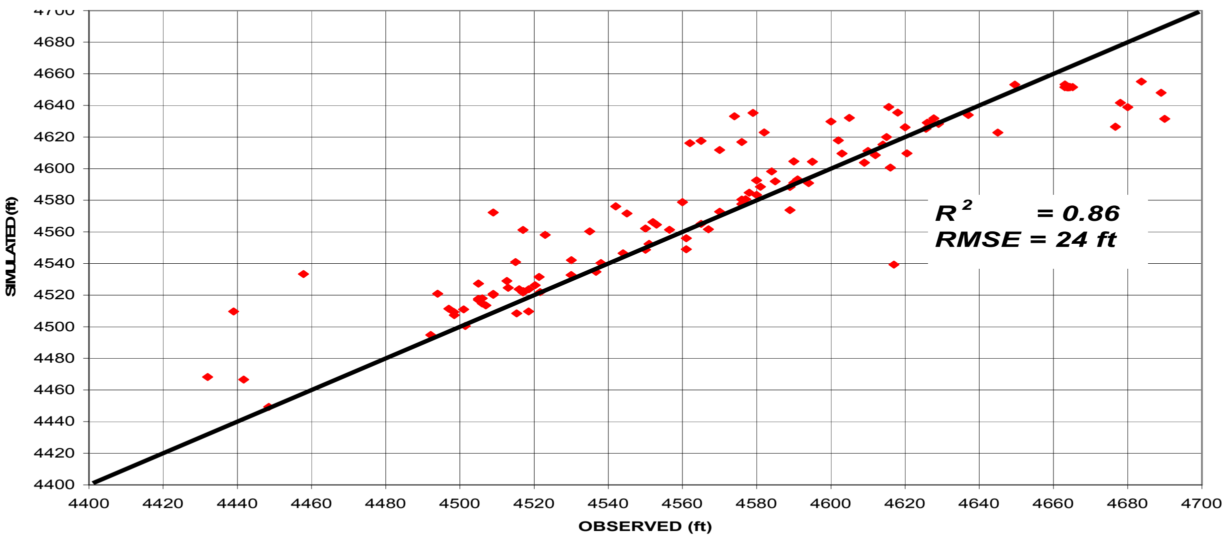


Figure 12. Measured vs Simulated Steady State Water Levels

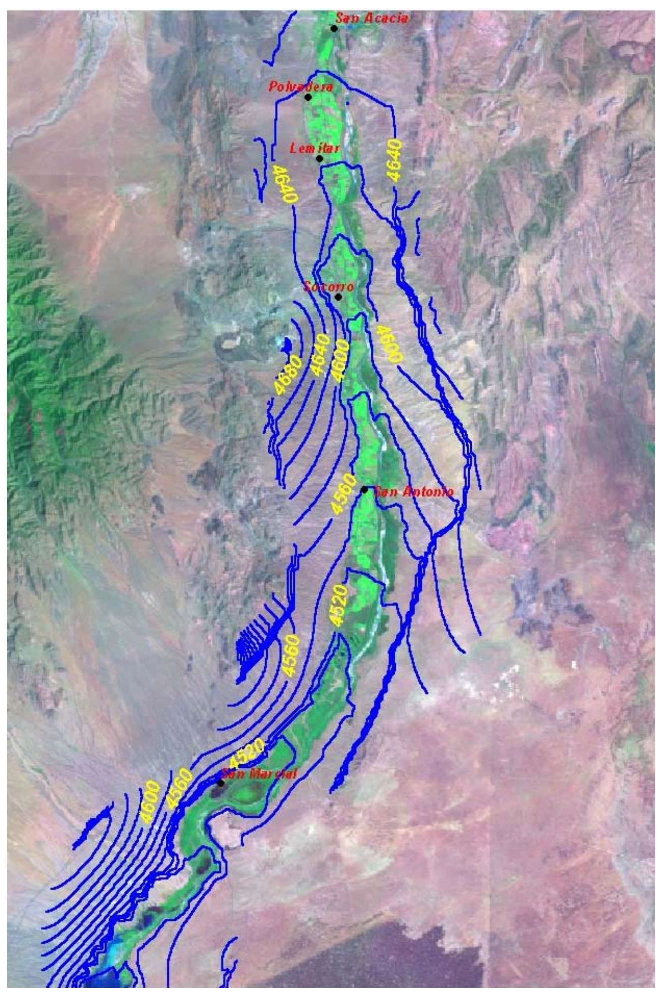


Figure 13. Simulated Steady State Water Levels

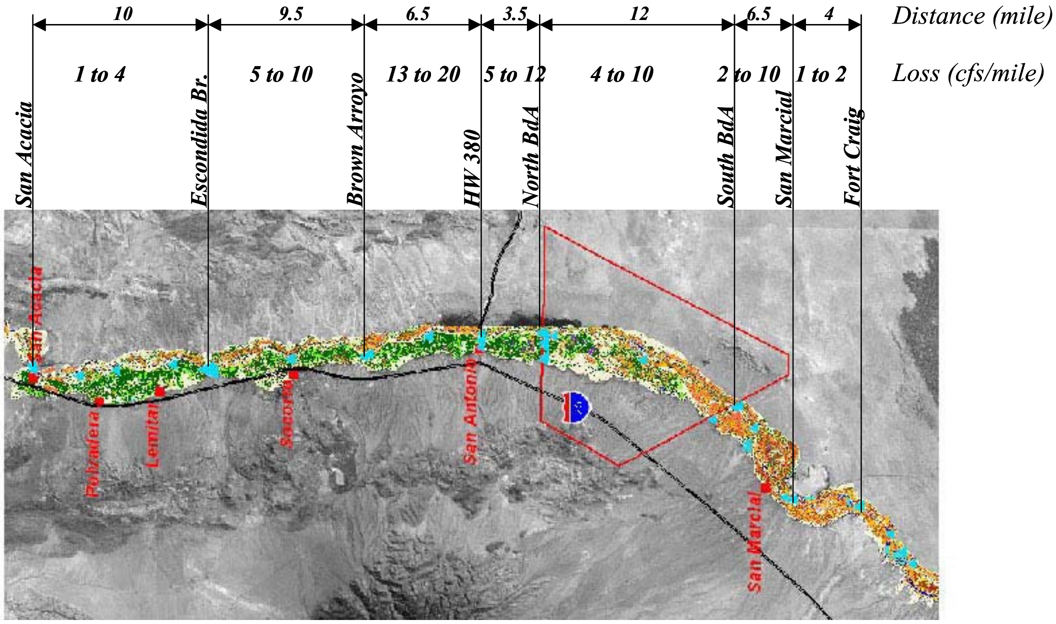


Figure 14. Summary of Rio Grande Seepage Runs

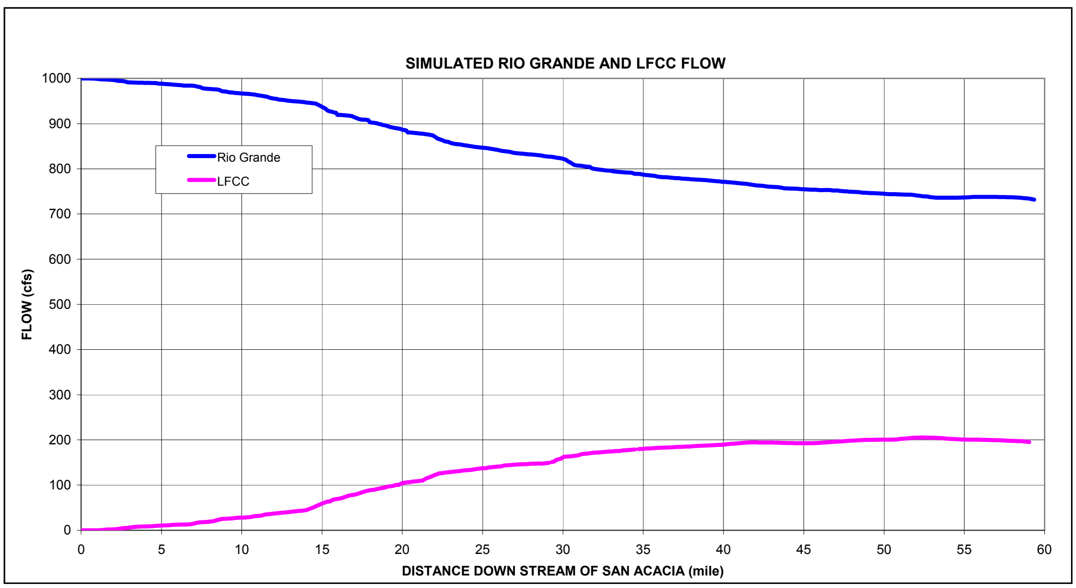


Figure 15. Steady State Rio Grande Seepage and LFCC Gain.

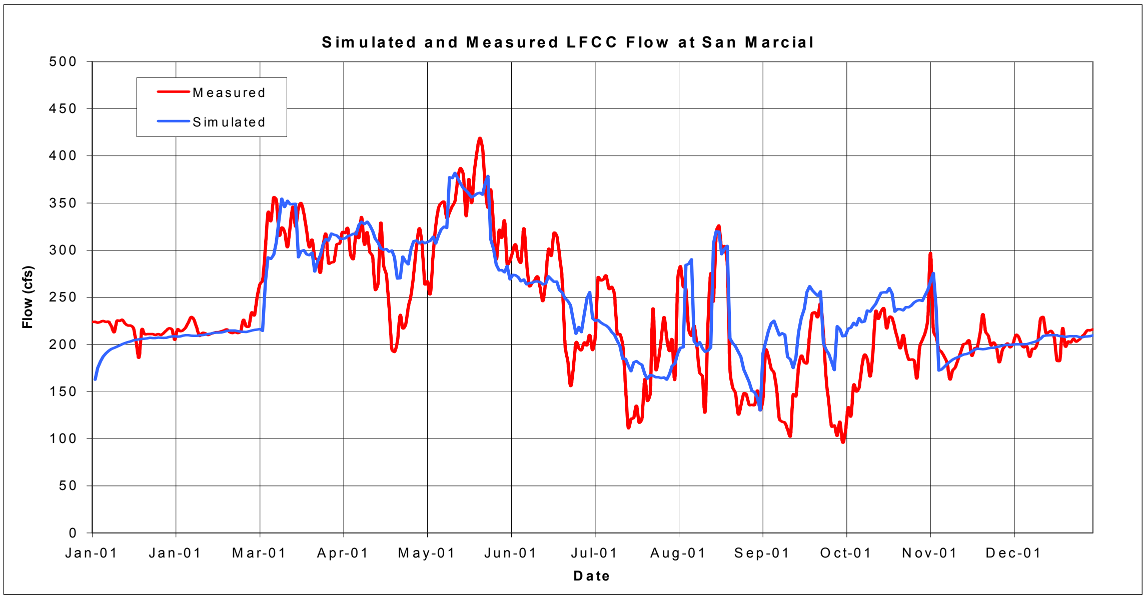
Table 2 illustrates the steady state budget for the basin. Results indicated that inflow to the basin from the Albuquerque basin is not significant. Total inflow to the system is about 220,000 afy with the Rio Grande as the major source to the system. Water discharges out of the system through the LFCC, riparian ET and the model southern boundary. The model estimates that about 65,000 afy are consumed by riparian vegetation in the basin. This is consistent with independent estimates using the BDA ET-tower data.

Table 2. Simulated Steady State Water Budget.

Inflow		Outflow	
Upper Basin	115 afy	GW Outflow	5430 afy
Mountain Front	15,210 afy	Riparian ET	63,030 afy
RG Loss	205,020 afy	LFCC Gain	152,140 afy
Total	220,345 afy	Total	220,600 afy

5.3 Transient Simulation

The model was run for one year on a daily stress period using the surface water inflow to the system of year 2001 using the steady state head as starting head. **Figure 16** illustrate the measured and simulated flow at San Marcial in the LFCC and the Rio Grande. Results indicate that the model is reasonably simulates the surface water routing through the system. **Figure 17-Figure 18** show the shallow water level at different location through the basin and areas with water table above land surface.



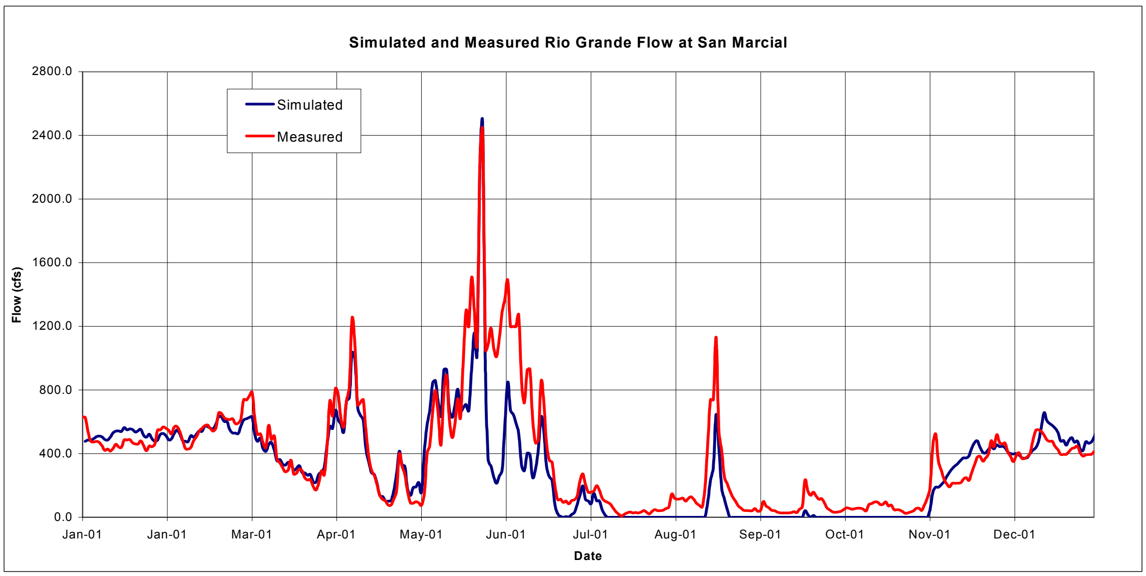
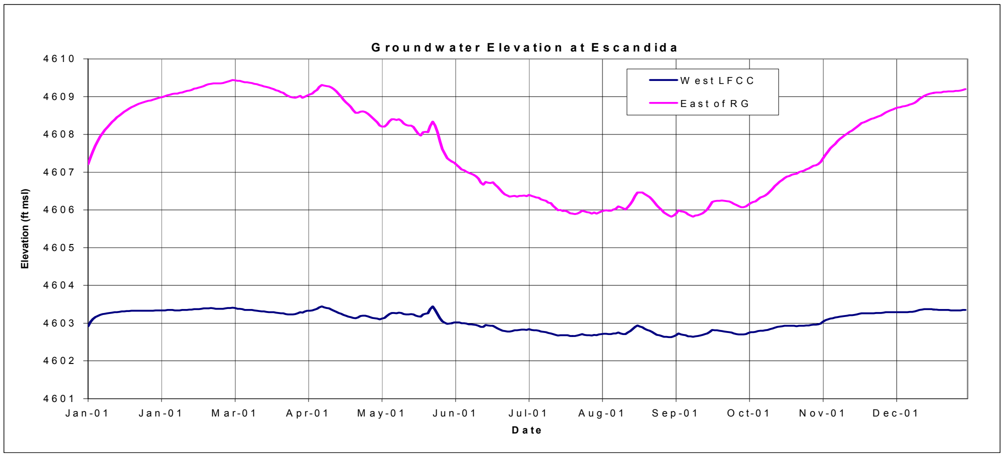
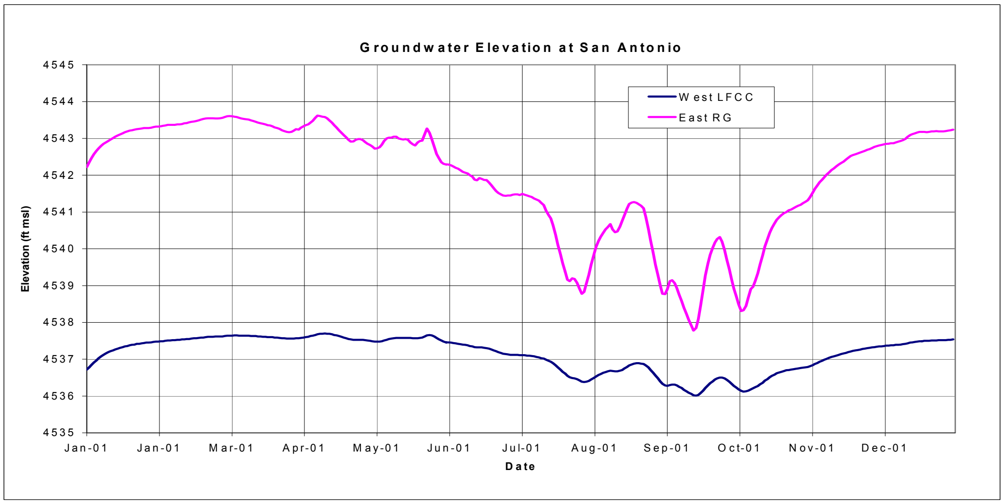


Figure 16. Simulated vs Measured flow at LFCC and Rio Grande at San Marcial





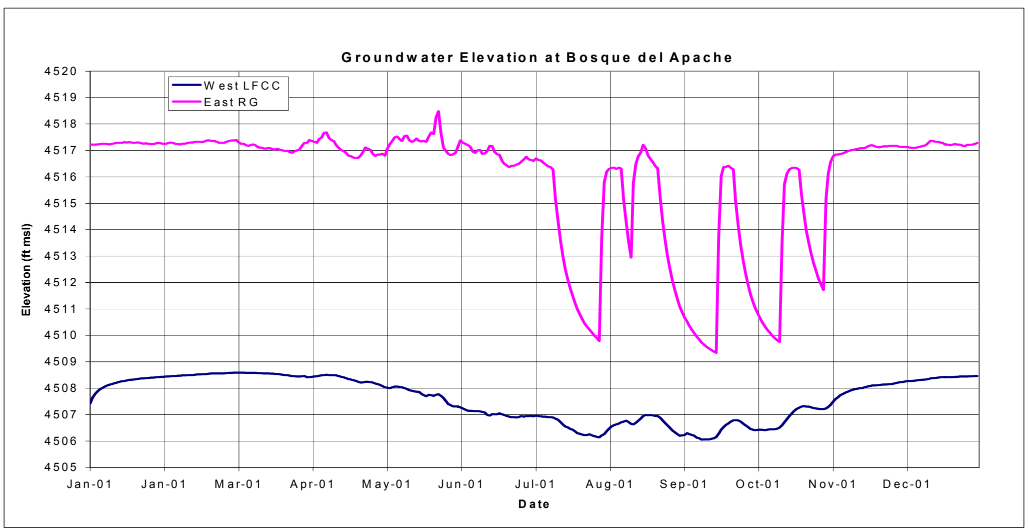


Figure 17. Simulated Water Levels at Selected Locations

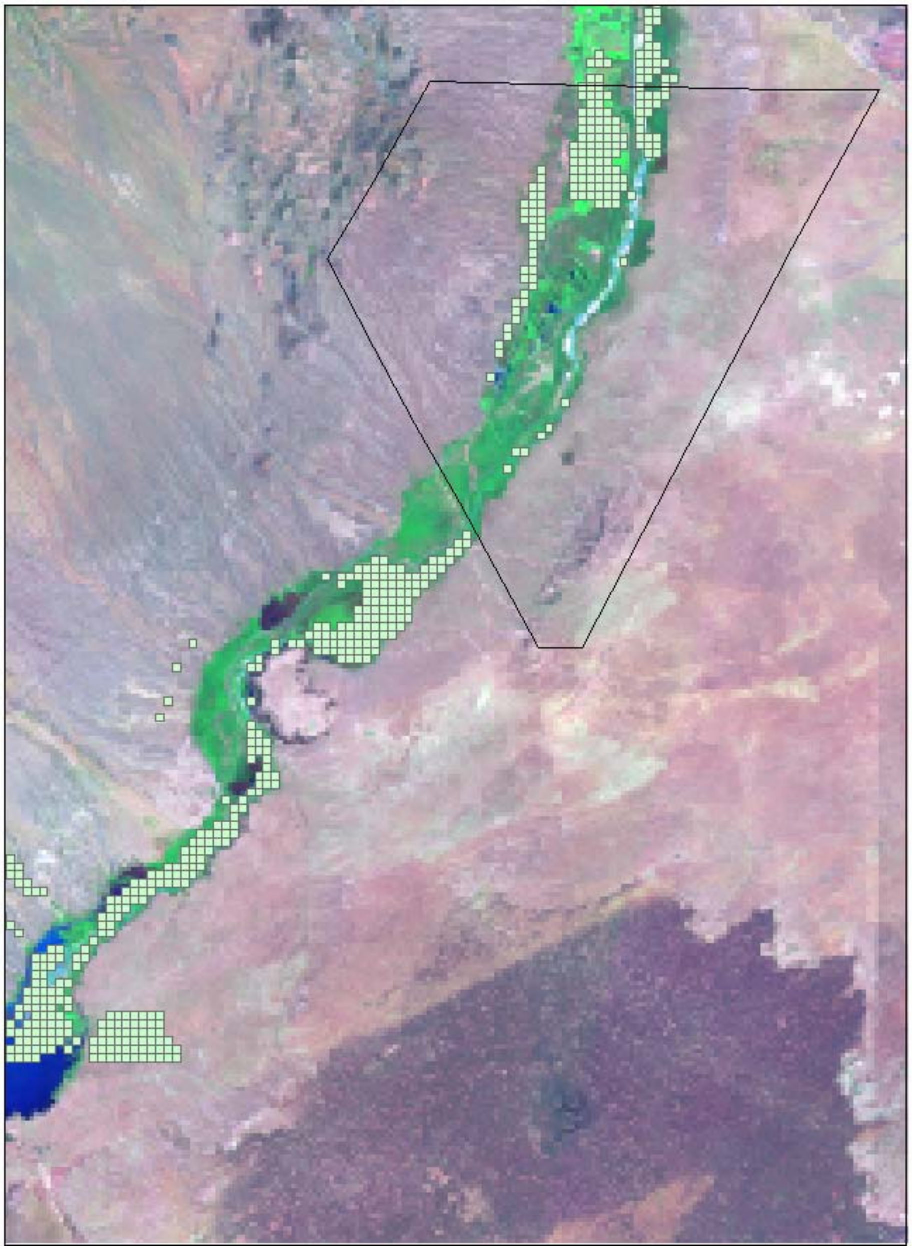


Figure 18. Map of Area with Water Table Above Land Surface (using 2001 hydrologic inflow).

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6.0 SUMMARY AND CONCLUSIONS

Linked surface water and groundwater model was developed for the Socorro and San Marcial basins. The model covers the area from San Acacia to the headwaters of the Elephant Butte reservoir. The model is designed to evaluate different operational alternatives of the LFCC. The model uses a unique surface water package to be able to rout surface water in the Rio Grande and the LFCC. The model simulates the shallow alluvial and the Santa Fe Group aquifers. Additional physical processes represented in the model are riparian and crop evapotranspiration.

The model was calibrated against water level data and flow data. Water level data mostly represent measured water levels in the shallow alluvial aquifer. Flow data represent the seepage loss of the Rio Grande and the Gain of the LFCC. Steady state and transient simulations were conducted and the results indicate that the model is adequately represents the hydrologic system.

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APPENDIX K
AQUATIC HABITAT MODEL

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1.0 Aquatic Habitat Model

1.1 Background

In order to evaluate the relative performance of the alternatives, the Aquatic Resources Team employed several contractors to formulate and construct a dynamic habitat-flow relationship capable of quantifying and modeling riverine habitat. Broadly defined, this approach combines the physical characteristics of a river, habitat use criteria for a given species, and hydrology data (in this case, URGWOM output) under a Geographic Information System (GIS) framework and calculates an explicit two-dimensional area of suitable aquatic habitat. The process of formalizing the Aquatic Habitat Model had four principal steps:

1) *Conceptual Approach* (Miller Ecological Consultants, Inc. and Science Applications International Corporation, 2000)
2) *GIS Model Report with Users Manual* (Miller Ecological Consultants, Inc., 2003)
3) *Pilot Hydraulic and Habitat Modeling Study* (Miller Ecological Consultants, Inc. and Mussetter Engineering, Inc., 2003)
4) Ecological Consultants, Inc., 2004)

Upon finalization of the alternatives and the subsequent completion of URGWOM output data, the Aquatic Habitat Model was used to produce a time series analysis of the 40-year hydrologic sequence in which daily flows were translated to a quantification of suitable habitat area for two representative study sites on the Rio Chama and six on the Rio Grande. These data were then used to evaluate the performance of the alternatives, for an array of indicator species, relative to the No Action.

The following are limited descriptions of the study sites as the length of above documents precludes their practical inclusion into this Review and EIS. In addition to Appendix K, more information on the study sites and results of the Aquatic Habitat Modeling effort can be found in Chapter IV. For more detailed information on the rationale, methods, and results of the Aquatic Habitat Model, any of the above referenced documents can be requested from the JLAs. When requesting these documents, please refer to the titles as stated in 1-4 above.

1.1.1 Study Site Descriptions

Seven sites that represent the geomorphologic variation within the Middle Rio Grande and the Rio Chama downstream of Abiquiu Reservoir were initially selected for analysis based on field reconnaissance and other available information **(Table K-1.1, Figure K-1.1)**. Subsequent to the initial selection, additional funding was obtained and a second site was added on the Rio Chama because of the significant variation in geomorphic characteristics between Abiquiu Reservoir and the mouth at the confluence with the Rio Grande. The criteria that were used to evaluate and select the sites included the following:

- Geomorphic representativeness of the reach, including the planform bed material and other morphological characteristics of the channel.
- The length of the reach that could reasonably be surveyed, with the goal of defining study reaches that were at least seven times longer than the average channel width. The target reach length is likely to encompass the geomorphologic variation in channel characteristics, including meso- and macro-scale features such as pools, riffles, subaerial (braid bars) and subaqueous (linguoid/lobate bars), all of which are in-channel features that are associated with in-channel aquatic habitat.
- Access to the site based on property ownership, as well as physical access for a boat to support intermediate-level flow measurements.

- Proximity to a gaging station to provide a means of accurately estimating the discharge at the sites during the surveys, and for quantifying the long-term flow characteristics in the analysis phase of the work.

Table K-1.1 Summary of sites selected for the hydraulic and habitat modeling study

Study Site	*Description**
Pena Blanca	Rio Grande at Pena Blanca (RM 227.5)
Bernalillo	Rio Grande at Bernalillo (RM 203.6)
Central	Rio Grande at Central Avenue Bridge (RM 183.2)
Bernardo	Rio Grande downstream of US 60 Bridge near Bernardo (RM 130.4)
Bosque del Apache	Rio Grande just downstream of north boundary of Bosque del Apache National Wildlife Refuge (RM 84.1)
San Marcial	Rio Grande below the San Marcial Railroad Bridge (RM 68.5)
Upper Rio Chama	Rio Chama about 3 miles downstream of Abiquiu Dam
Lower Rio Chama	Rio Chama just upstream of new Highway 285 Bridge

*River Miles along the Rio Grande represent the approximate mid-point of the modeled reach and are based on the 1997 U.S. Bureau of Reclamation River Atlas.

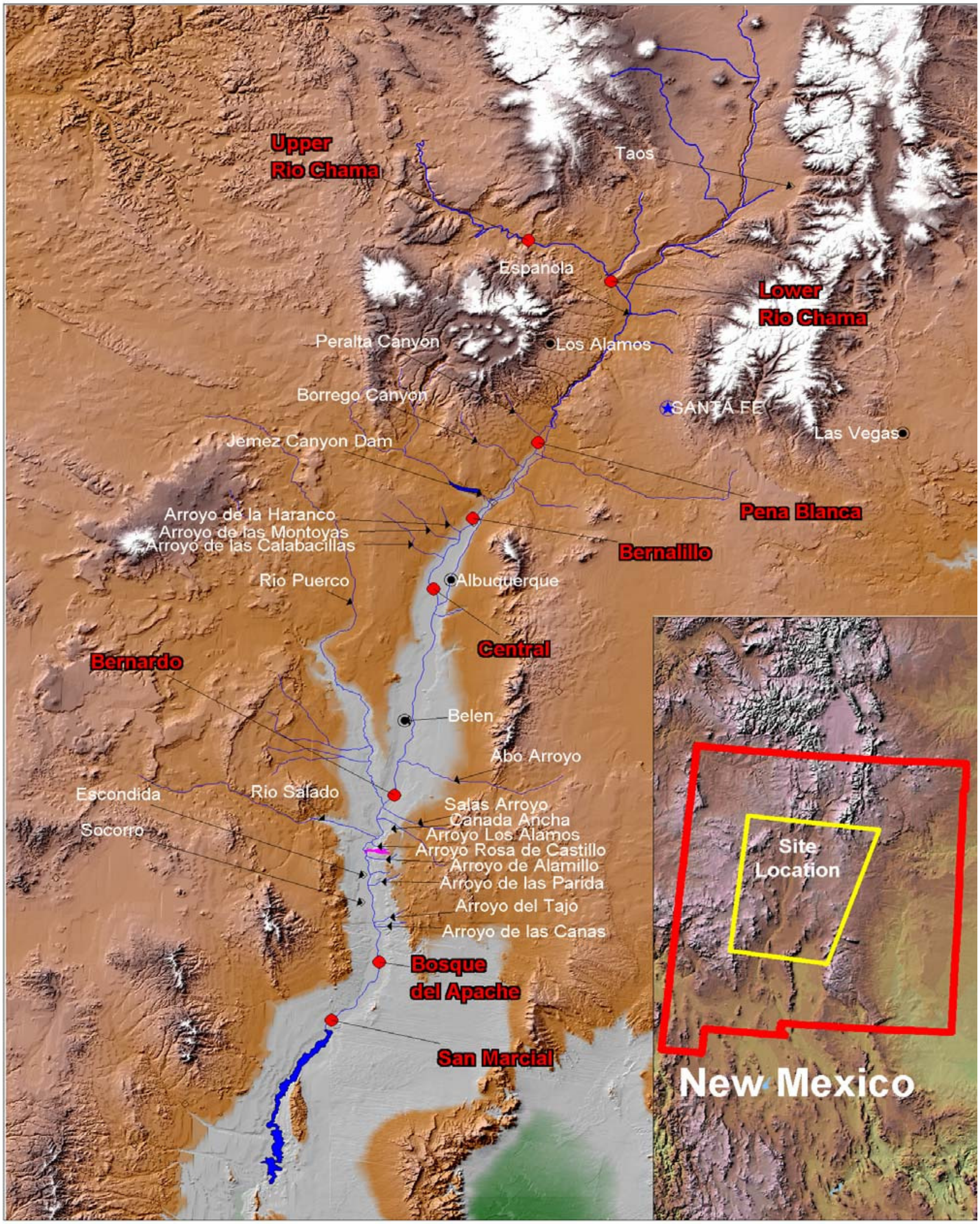

Figure K-1.1 Map of the Middle Rio Grande showing locations of the study sites selected for the hydraulic and habitat modeling study.

1.2 Rio Grande at Pena Blanca (Pena Blanca)

The Pena Blanca study site is located at approximately River Mile (RM) 227.5 between the southern boundary of the Cochiti Pueblo Reservation and the northern boundary of the Santo Domingo Pueblo Reservation. The site is about 0.6 miles long, the active channel width is about 150 feet, and the average gradient is about 10 feet per mile. This reach of the Rio Grande is characterized by split flows around vegetated bars and islands, and it has relatively coarse, gravel- and cobble-sized bed material due, in part, to winnowing of fines as a result of reduced upstream sediment supply since Cochiti Dam was constructed in 1973. Based on Bureau of Reclamation range line bed material samples in the vicinity of the site, the median (D_{50}) size of the bed material is about 19 mm, and the D_{84} is about 58 mm. Some sediment is still supplied to the reach by Peralta Canyon Arroyo located about 2 miles upstream of the site. Analysis of the effects of Cochiti Dam on the downstream morphology of the channel indicates that the bed of the channel at the study site has probably degraded by about 2 feet since the dam was closed (Lagasse, 1980; Leon, 1998; Mussetter Engineering, Inc. (MEI), 2002), but it is unlikely that further degradation will occur because the bed has armored. The study site includes split flow around a large island with several smaller splits that occur at low flows. Single-channel segments are located both upstream and downstream of the split-flow reach. A number of low elevations, formerly (pre-Cochiti) active gravel braid bars are located through the site and these are heavily vegetated with willows and Russian olive trees. The pre-incision floodplain is densely vegetated with primarily tamarisk and Russian olive trees, but there are also some large cottonwoods. The site is bounded to the east by the levee on the west side of the Cochiti East Side Riverside Drain, and to the west by an informal levee that is located along the west bank of the river.

1.3 Rio Grande at Bernalillo (Bernalillo)

The Bernalillo study site is located at approximately RM 204 just downstream of NM Highway 550 at Bernalillo. The site is about 1,800 feet long, the active channel width is about 500 feet and the average gradient is about 2.5 feet per mile. This reach of the Rio Grande is characterized by a braided high flow planform, with a number of relatively high-elevation vegetated bars present in the channel. Under low flow conditions the reach has a single channel with low sinuosity. The reach has degraded since the sediment supply to the reach was reduced by construction of Jemez Reservoir in 1954 and Cochiti Reservoir in 1973. Between 1973 and 1998 the mean elevation of the bed of the river decreased by 2 feet (Bauer, 2000; MEI, 2002), and degradation may be on-going. Associated with the channel degradation has been coarsening of the bed material. In 1970 the D_{50} of the bed material was about 0.3 mm, but by 1998 it had coarsened to about 8 mm (MEI, 2002). Currently, the riffles within the reach are composed of gravels, but no recent gradation analyses are available for the reach. It is likely, however, that the bed of the river will further coarsen with time. The reach is confined on the east side of the river by the levee that is located on the west side of the Bernalillo Riverside Drain. Jetty jacks are present along the left bank of the river and on the floodplain between the river bank and the levee. The west side of the reach is bounded by the pre-incision floodplain, the bank of which is actively being eroded by the river. Urbanization of the floodplain will probably result in armoring of the bank. The pre-incision floodplain on both sides of the river is heavily vegetated with a mixture of tamarisk, Russian olive, elm and cottonwoods.

1.4 Rio Grande at Central Avenue Bridge (Central)

The Central study site is located just downstream of the Central Avenue Bridge in Albuquerque at about RM 183. The site is about 2,700 feet long, the active channel width is about 500 feet and the average gradient is about 2.6 feet per mile. This reach of the Rio Grande is characterized by a slightly sinuous meandering planform caused by the stabilization of bank-attached bars with native and introduced vegetation species, and the presence of Kelner Jack fields. The study site includes a split-flow segment around a vegetated (willows and Russian olive) mid-channel bar that provides a range of channel sizes within the site. All of the channel segments contained subaerially exposed sandy braid bars, and subaqueous, migrating linguoid bars, the spacing of which, scale to the width of the individual active channels. Analysis of the U.S. Geological Survey (USGS) discharge rating curves for the Albuquerque gage located at the Central Avenue Bridge indicates that there has been about 2 feet of downward shift in the rating curves between 1974 and 2001 (MEI, 2002). This suggests that there has been about 2 feet of bed lowering in the reach since the upstream dams were emplaced. The amount of degradation is corroborated by review of the Bureau of Reclamation range lines in this location that show about 2 foot of reduction of mean bed elevation between 1973 and 1998 (MEI, 2002), but these data indicate that there has been bed stability since 1998. The bed material in the reach is primarily sand sized, but there are local concentrations of gravels on the riverbed. Analysis of bed material gradations at the gage from 1968 to 2001 indicates that the D_{50} of the bed material has coarsened slightly over time from about 0.3 mm to 0.5 mm, but the D_{84} values have remained consistently at about 10 mm (MEI, 2002). The river is bounded to the east by the levee located on the west side of the Albuquerque Riverside Drain, and to the west by the levee that is located on the east side of the Atrisco Riverside Drain. Kelner jacks are located on the floodplain surface on both sides of the river, and both sides of the floodplain are heavily vegetated with tamarisk, Russian olive, elm, willows and cottonwoods.

1.5 Rio Grande Downstream of US 60 Bridge near Bernardo (Bernardo)

The Bernardo study site is located just downstream from the U.S. Highway 60 Bridge near Bernardo at about RM 130. The study site is about 2,500 feet long, and has an average channel width of about 600 feet. This width is about 40 percent wider than the average width of the Rio Grande in the approximately 13-mile reach between the mouths of the Canada Ancha Arroyo, located about 4.2 miles downstream from the Highway 60 Bridge, and Belen (MEI, 2002). The reach is characterized by a wide, braided, sand-bed channel with numerous vegetated and non-vegetated mid-channel bars, sandy braid bars, and migrating subaqueous linguoid bars. The average gradient of the Rio Grande in this reach is about 4.7 feet per mile. Analysis of Bureau of Reclamation range lines surveys between 1962 and 1998 indicates that there has been about 2 feet of bed lowering in this reach of the river (Bauer, 2000) The degradation was most probably due to channelization of the river, and may also be related to the increased flows that have occurred in the reach as a result of importation of San Juan-Chama water to the basin as well as increased wastewater discharges from the City of Albuquerque (MEI, 2002). The sandy bed material at the site is mobile over essentially the entire range of flows that occur in the reach, and bedforms ranging from ripples to remnant dunes are evident under low-flow conditions. The D_{50} of the bed material is about 0.2 mm, and this has not changed since 1968 (MEI, 2002). Hydraulic variability through the site is created by flow deflection around the micro- and meso-scale bedforms, local scour holes and plunge pools that develop on the downstream side of the linguoid bars and at locations where flow impinges on the relatively erosion-resistant banks. Jetty-jacks line the channel along both sides of the river, resulting in well-defined, erosion-resistant banklines that are vegetated with a mixture of primarily salt cedar and Russian olive. The channel is bounded on the east side by the levee that is located on the west side of the San Juan Riverside Drain and on the west side by the levee that is located on the east side of the San Francisco Riverside Drain. The floodplain on each side of the river is densely vegetated with a mixture of tamarisk, Russian Olive and cottonwoods.

1.6 Rio Grande just Downstream of North Boundary of Bosque del Apache National Wildlife Refuge (Bosque del Apache)

The Bosque del Apache study site is located just downstream of the north boundary of the Bosque del Apache National Wildlife Refuge at about RM 84. The site is about 2,500 feet long, the average channel width is about 700 feet, and the average gradient is about 3.3 feet per mile. This site is located in a relatively straight reach of the Rio Grande that is characterized by the presence of alternate bars with a wavelength of about 4,000 feet. The alternate bars create low-flow sinuosity in a reach of the river where it is braided at higher flows. The alternate bar, which is attached to the right (west) bank of the river, extends for the entire length of the site. At the time of the site surveys, the bar was composed of two main surfaces: (1) a subaerially exposed sand bar devoid of vegetation, and (2) a predominantly willow-dominated vegetated sand bar at a somewhat higher elevation. A pre-existing secondary channel between the west margin of the alternate bar and the primarily cottonwood dominated vegetated floodplain extends for most of the length of the site, and was being used at the time of the survey to convey pumped flows from the Low Flow Conveyance Channel (LFCC) to the river. The floodplain along the east (left) bank of the river is primarily vegetated with tamarisk and Russian olives whose roots provide root reinforcement to the sandy floodplain sediments, thereby, limiting the erosion potential. Under low-flow conditions, subaqueous linguoid bars whose spacing scaled to the width of the active channel were present throughout the site. Bed and bar sediments are composed primarily of medium-fine sands, but thick clay-dominated drapes were present on many of the bar surfaces. Some fine gravel was observed in the bed and bar sediments as well, and was probably derived from the east-side tributaries located upstream of the Highway 380 bridge. The D_{50} of the bed material is about 0.3 mm. The site is bounded to the east by an abandoned historic levee and to the west by the levee on the east side of the LFCC.

1.7 Rio Grande below the San Marcial Railroad Bridge (San Marcial)

The San Marcial study site is located just downstream of the San Marcial Railroad Bridge at about RM 69. The site is about 2,700 feet long, the average channel width is about 250 feet and the average gradient is about 2.0 feet per mile. This reach of the Rio Grande is characterized by active channel aggradation as a result of base-level control exerted by Elephant Butte Reservoir. Comparative surveys indicate that the bed of the river has aggraded about 24 feet in this reach since 1885 (Smith et al., 2001). The river channel within this reach is entirely man-made and is relatively narrow, and is somewhat further constricted by the BNSF railroad bridge. Numerous sandy braid bars and subaqueous, migrating linguoid bars are present within the channel. The D_{50} of the bed material is about 0.2 mm (MEI, 2002). The hydraulic capacity of the BNSF railroad bridge, located immediately upstream of the reach, is about 3,800 cfs (Smith et al., 2001), and this limits the magnitude of the controlled flow releases from upstream. Higher peak flows derived primarily from summer thunderstorm flows in the Rio Puerco and Rio Salado drainages may exceed the bridge capacity. The east side of the site is bounded by Mesa del Contradero, a Cenozoic-age volcanic-capped mesa. The west side of the site is bounded by the levee on the east side of the LFCC. The floodplain on the west side of the river is very heavily vegetated.

1.8 Rio Chama Downstream of Abiquiu Dam (Upper Rio Chama)

The Upper Rio Chama at this site, which is located about 3 miles downstream of Abiquiu Dam, is canyon bound and has very coarse bed material composed primarily of cobbles and boulders. The coarse nature of the bed material may be in part due to the elimination of bed material sediment supply from upstream by the dam. The site is about 2,500 feet long, the active channel width in the single channel portion of the reach is about 250 feet and the average gradient is about 14 feet per mile. The modeled reach includes a large vegetated mid-channel bar that owes its existence to a downstream constriction formed by horizontally-opposed tributary alluvial fans. A low elevation bench-like surface is present around the margins of the mid-channel bar and on the banks of the river, and this probably represents the morphological adjustment of the river to closure of the dam in 1963. Coarse material delivered by the downstream tributaries helps to maintain the constriction that is the downstream hydraulic control for the large mid-channel bar. Two vegetated secondary bars are present in the right channel. A right bank tributary located upstream of the modeled reach provides sediment to the reach, which otherwise has a low sediment supply because of the presence upstream of Abiquiu Dam. The planform of the river just upstream of the modeled reach is controlled by bedrock outcrop. Bedrock outcrop (Triassic-age Chinle Formation) crops out in the right bank of the river near the downstream end of the reach, but the remainder of the right bank is comprised of a gravel-capped strath terrace. Bedrock outcrop and the margin of the left bank alluvial fan bound the river on the east side of the reach. This site was chosen by the COE to represent brown trout fishery habitat in the reach of the river below the dam.

1.9 Rio Chama Upstream of new Highway 285 Bridge (Lower Rio Chama)

The Lower Rio Chama Site is located about 2,000 feet upstream of the Highway 285 Bridge near Chamita and was added to the study to represent conditions in the lower portion of the Rio Chama that are very different to the canyon-bound reach represented by the upper study site. The study site is about 2,500 feet long, and it has an average channel width of about 200 feet and an average gradient of about 6.5 feet per mile. The modeled reach is relatively straight and uniform. The left bank of the river in the modeled reach is composed primarily of sediments deposited on the alluvial fan of Rio Ojo Caliente, a left bank tributary whose present confluence with the Rio Chama is located about 2000 feet upstream of the modeled reach. The fan surface is primarily vegetated with cottonwoods. The right bank of the river is composed of Rio Chama sediments that have been stabilized in the post-dam era by primarily non-native vegetation species and jetty jacks. A levee has been constructed on the historic floodplain and has cutoff a former channel of the river that was located to the south of its present position. The bed of the river at this site is composed primarily of gravels and cobbles. Sands that are delivered from the numerous tributary arroyos that drain the Santa Fe Formation, that forms the basin fill upstream of the reach, are transported over the gravels and cobbles when discharges in the river are less than critical for mobilization of the bed material. A low elevation berm that is vegetated with willows and small Russian olives has formed along both banks of the river in response to flood flow control by Abiquiu Dam. A right bank un-named tributary arroyo forms a fan about 600 feet upstream of the highway bridge that extends out into the channel of the Rio Chama. Small boulders and cobbles derived from the fan form a coarse-grained riffle at the confluence and this provides a stable baselevel for the upstream channel of the Rio Chama.

1.9.1 Field Data Collection

Field data were collected by MEI and Bohannan Huston Inc. (BHI) at each of the study sites to obtain the data necessary to develop and verify the 2-D hydraulic models. The data collection program included a topographic survey of the channel and overbanks, paired depth and velocity measurements that were geo-referenced to each site survey, and general descriptive information about each site. Water-surface elevations were also collected as part of the topographic survey for use in validating the modeled water-surface elevations. Data were collected during two site visits at each site to obtain data for use in model calibration at different flow levels. **Table K-1.2** summarizes the dates of the surveys and the discharges and number of depth and velocity measurements made during each site visit. Average discharges provided in **Table K-1.2** are based on flow measurements conducted during the survey, or available data from the nearest USGS stream gage. Where both flow measurements and data from a nearby stream gage were available, the decision on which data to use was based on judgment as to the accuracy of the flow measurements, the closeness of the gage to the site, the presence of diversions or tributaries between the gage and the site, and published remarks as to the accuracy of the flow records at the gage.

The topographic surveys were conducted using a survey-grade Global Positioning System (GPS) and total station theodolite, with the surveys tied to the state-plane coordinate system (New Mexico Central Zone, North American Datum of 1983 (NAD83) for the horizontal datum. At sites where preliminary work was performed by others before BHI's involvement in the project, the National Geodetic Vertical Datum of 1929 (NGVD29) was used for the vertical datum along with local control points. At sites where BHI established the local control, the North American Vertical Datum of 1988 (NAVD 88) was used for the vertical datum. This included the two sites on the Rio Chama as well as the Central Ave. site on the Rio Grande. BHI used the field survey data, in conjunction with aerial photography of each site that was flown prior to the field surveys, to create a 1-foot contour interval topographic map of each study site.

Table K-1.2 Summary of site surveys

Study Site	First Site Visit			Second Site Visit		
	Survey Dates	Average Discharge (cfs)	Number of Depth-Velocity Pairs	Survey Dates	Average Discharge (cfs)	Number of Depth-Velocity Pairs
Pena Blanca	Feb 9-10, 2002	544[1]	121	Oct 3, 2002	295[1]	44
Bernalillo	Jan 28-29, 2002	514[m]	93	Oct 2, 2002	247[m]	39
Central Avenue	Jan 30-31, 2002	462[m]	179	Sep. 30-Oct. 1, 2002	197[m]	80
Bernardo	Feb 1-2, 2002	605[2]	108	Apr 26, 2002	7[2]	0
Bosque del Apache	Feb 3-4, 2002	454[m]	95	Apr 24-25, 2002	76[m]	178
San Marcial	Feb 5-6, 2002	477[3]	149	Apr 22-23, 2002	46[3]	97
Upper Rio Chama	Feb 7-8, 2002	18[m]	135	Oct 8-9, 2002	220[m]	85
Lower Rio Chama	Jul 11-12, 2002	916[4]	186	Dec 10, 2002	73[4]	119

[m]Measured flow at the site

[1]Average flow at the Rio Grande below Cochiti Dam stream gage

[2]Average flow at the Rio Grande Floodway near Bernardo stream gage

[3]Average flow at the Rio Grande Floodway at San Marcial stream gage

[4]Average flow at the Rio Chama near Chamita stream gage

Notes:
1. All sites were surveyed in US survey feet.
2. All sites were surveyed in Modified State Plane Coordinates, Central Zone.
3. All sites were surveyed in North American Datum 1983, North America Vertical Datum 1988, except Bosque del Apache and San Marcial.
4. Bosque del Apache and San Marcial were surveyed in North American Datum 1927 and North America Vertical Datum 1988.

1.9.2 Limitations of the Aquatic Habitat Model

The Aquatic Habitat Model was formulated to evaluate riverine habitat and does not address impacts within reservoirs. Moreover, the Aquatic Habitat Model is functionally limited to quantitatively evaluating alternative impacts in the areas defined by the study sites only; however, again, these regions were selected to be representative of larger reaches. Viewed in this way, the habitat behavior of the larger reaches can be expected to follow the general trend of the associated study site (*i.e.* a gain or lose aquatic habitat) but direct extrapolation or proportional scaling of study site gains or losses cannot be attempted with the available data. In addition, the model is limited to evaluating habitat within the active channel and cannot address overbank (floodplain) areas.

An additional limitation of the Aquatic Habitat Model concerns the limited availability of calibration flows. Again, the Aquatic Habitat Model ultimately depends upon a measured relationship between species-specific habitat preferences (a bi-variate correlation of both depth *and* velocity) and the physical characteristics and hydraulic behavior of the river at differential flows. The model applies the habitat use preferences to the physical behavior of the river and calculates the two-dimensional extent (in $ft.^2$) of useable habitat for a given input flow, with respect to depth *and* velocity, and tabulates a time series dataset of habitat extent. As such, the hydraulic modeling portion (RMA2, Version 4.35) of the larger Aquatic Habitat Model requires a calibration that measures depth and velocity at a range of flows. Table **XX** below shows the survey dates, average discharge, and number of depth/velocity paired measurements that were taken during field data collection. All RMA2 calibration took place in 2002; a drought of record year. As a result, the high-flow calibration datasets tend to be lower than average flows and therefore limit the ability to fully understand the hydraulic behavior of the river and study sites at higher flows. Thus, confidence in the habitat predictions of the Aquatic Habitat Model should be considered somewhat bounded by the upper limits of the calibration flows shown in **Table XX,** and confidence in any predictions beyond these upper limits is limited. Nonetheless, the Aquatic Habitat Model is generally considered robust as the frequency of exceeding the upper calibration flows are low with respect to the 40-year sequence (n = 14,610 = daily average flow of modeled URGWOM hydrology – used as Aquatic Habitat Model input data in alternative evaluation).

Thus, the interpretive limitations of the Aquatic Habitat Model can be summarized as follows:

1) Aquatic Habitat Model results and conclusions are valid for riverine habitat only,
2) The model only evaluates habitat for the active channel and, by construction, cannot address potential floodplain habitat during overbank events,
3) Extrapolation of results to larger river reaches was not attempted and habitat quantification is valid for the study sites only – however, study sites were chosen to be generally representative of larger reaches,
4) Lack of high-flow calibration of the RMA2 hydraulic model limits the confidence of subsequent habitat predictions.

All of these inherent limitations should be considered data gaps and subject for refinement and/or improvement when future actions are proposed and further defined. Subsequent to the formulation and use of the Aquatic Habitat Model in this Review and EIS, significant methodological improvements have occurred and should be strongly considered in future analyses.

1.9.3 Selected Results of the Aquatic Habitat Model

The following are selected results of the Aquatic Habitat Model. Included here, is an example of the results derived from the Aquatic Habitat and Hydraulic Model for the Rio Grande at Central Avenue

Bridge (Central) study site for Rio Grande Silvery Minnow (RGSM) adult. Again, for a complete account of all sites, species, and life stages the Aquatic Habitat Model addressed, the *Final Aquatic Habitat and Hydraulic Modeling Study for the Upper Rio Grande Water Operations Model* (Bohannon Houston, Inc., Mussetter Engineering, Inc., and Miller Ecological Consultants, Inc., 2004) should be requested and referenced (also noted in the *Background* Section above). This report, and additional Aquatic Habitat Model documentation and data, are available by request from the JLAs.

Topographic survey data was used to produce one-foot contour maps of all study sites (Central is shown in **Figure 1-2** below). These data were used, in combination with the paired depth/velocity measurements, RMA2 hydraulic modeling, and species-specific habitat use data to ultimately derive a two-dimensional, spatially explicit GIS surface that quantifies the weighted aquatic habitat (in terms of suitability) with respect to calibration flows. This GIS based habitat-flow polynomial relationship (**Figure 1-3**) is then used to calculate a time-series dataset of habitat values for the flows output from the 40-year URGWOM planning sequence for all alternatives (**Figure 1-4**).

Figure K-1.2 One-foot contour map of the Central study site

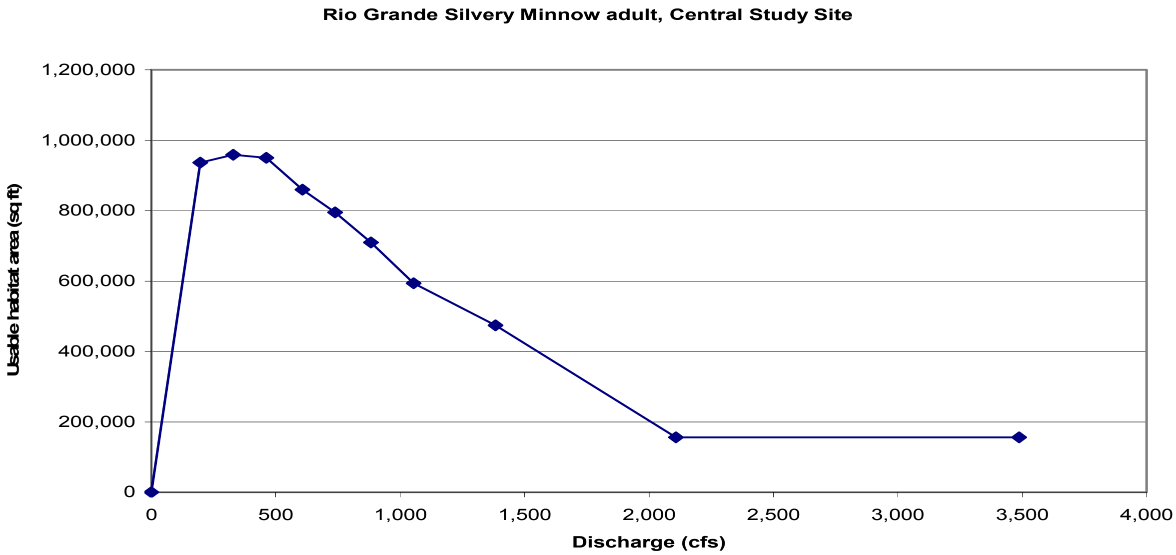

Figure K-1.3 Habitat-flow relationship of the RGSM at Central Study Site

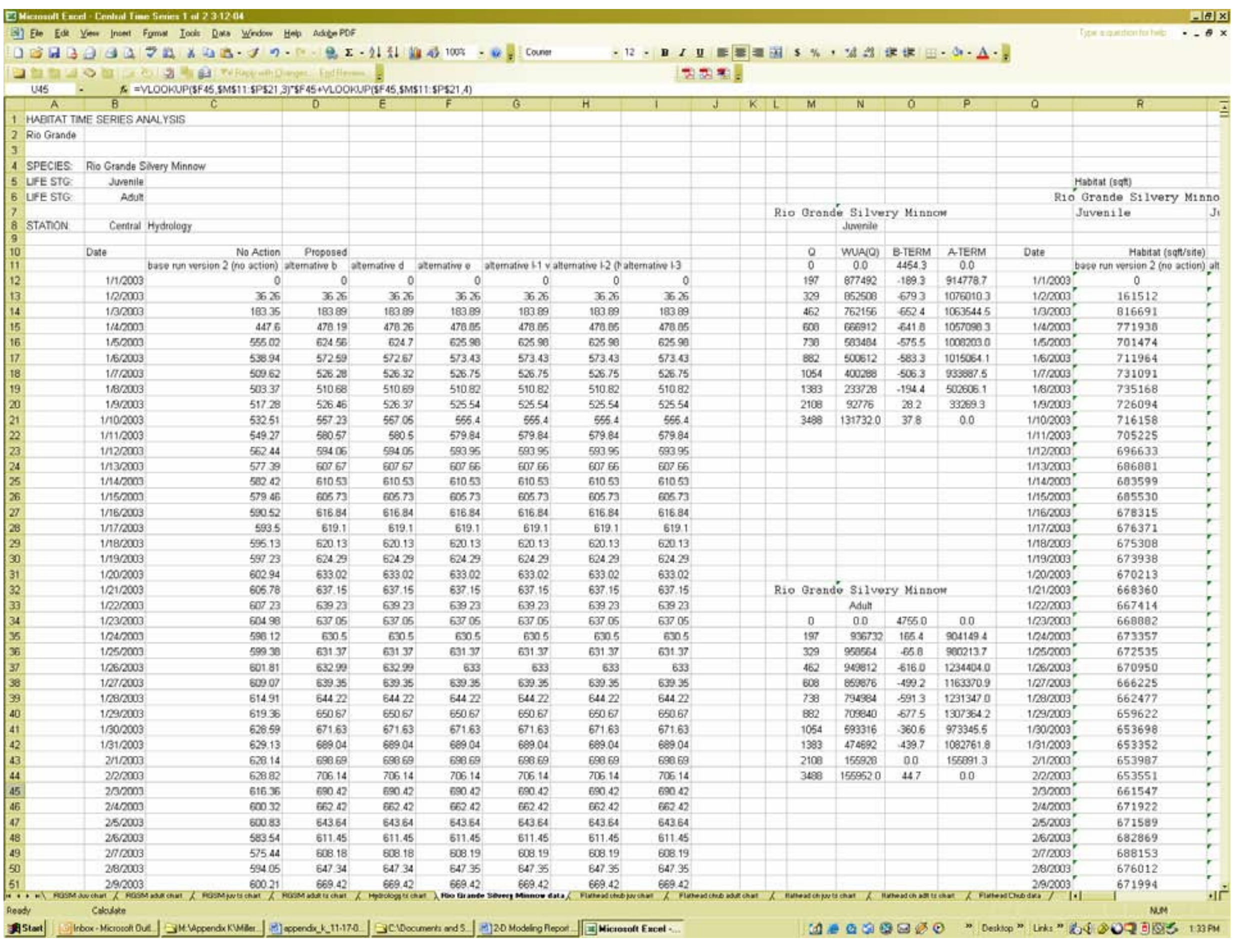

Figure K-1.4 Habitat time-series analysis – Central study site, RGSM

1.9.4 Tabulated Results of all Study Sites, Species, and Life Stages

The following are tabulated results for the time-series analyses for all sites, species, and life stages. Modeling analyses did not have sufficient habitat use criteria for River Carpsucker, adult Values indicate the mean habitat (ft.^{2}) for the 40-year planning sequence, difference from No Action alternative, and percent change from No Action alternative. Note negative values indicate a loss of habitat.

1.9.4.1 Rio Grande at Pena Blanca Study Site

Rio Grande Silvery Minnow
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	233,325.1	221,988.8	225,209.2	224,177.6	231,941.7	226,197.1	224,364.7
Difference Gained or Lost from No Action (ft^2)	0.0	-11,336.2	-8,115.9	-9,147.5	-1,383.3	-7,127.9	-8,960.3
Percent Change from No Action (%)	0.0	-4.9	-3.5	-3.9	-0.6	-3.1	-3.8

Rio Grande Silvery Minnow
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	306,259.1	292,993.1	296,894.6	295,631.9	304,691.4	297,996.7	295,779.7
Difference Gained or Lost from No Action (ft^2)	0.0	-13,266.0	-9,364.6	-10,627.2	-1,567.8	-8,262.4	-10,479.5
Percent Change from No Action (%)	0.0	-4.3	-3.1	-3.5	-0.5	-2.7	-3.4

Flathead Chub
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	90,763.1	85,555.3	86,869.9	86,469.3	90,153.9	87,661.3	86,606.3
Difference Gained or Lost from No Action (ft^2)	0.0	-5,207.8	-3,893.2	-4,293.8	-609.2	-3,101.7	-4,156.8
Percent Change from No Action (%)	0.0	-5.7	-4.3	-4.7	-0.7	-3.4	-4.6

Flathead Chub
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	192,563.8	185,508.0	187,544.9	186,940.3	192,276.9	189,442.0	186,981.4
Difference Gained or Lost from No Action (ft^2)	0.0	-7,055.8	-5,018.8	-5,623.5	-286.8	-3,121.8	-5,582.4
Percent Change from No Action (%)	0.0	-3.7	-2.6	-2.9	-0.1	-1.6	-2.9

Longnose Dace
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	56,880.3	53,840.2	54,604.5	54,377.3	56,737.1	55,394.1	54,434.9
Difference Gained or Lost from No Action (ft^2)	0.0	-3,040.0	-2,275.8	-2,503.0	-143.2	-1,486.2	-2,445.4
Percent Change from No Action (%)	0.0	-5.3	-4.0	-4.4	-0.3	-2.6	-4.3

Longnose Dace
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	280,455.4	275,509.2	277,493.5	276,815.5	280,582.1	278,659.4	276,591.2
Difference Gained or Lost from No Action (ft^2)	0.0	-4,946.1	-2,961.9	-3,639.9	126.7	-1,795.9	-3,864.2
Percent Change from No Action (%)	0.0	-1.8	-1.1	-1.3	0.0	-0.6	-1.4

River Carpsucker
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	82,107.2	78,075.6	79,047.8	78,738.5	81,523.4	79,564.3	78,859.6
Difference Gained or Lost from No Action (ft^2)	0.0	-4,031.5	-3,059.4	-3,368.7	-583.8	-2,542.9	-3,247.5
Percent Change from No Action (%)	0.0	-4.9	-3.7	-4.1	-0.7	-3.1	-4.0

Channel Catfish
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	172,970.0	164,288.6	166,610.6	165,894.0	171,797.7	167,452.8	166,085.7
Difference Gained or Lost from No Action (ft^2)	0.0	-8,681.4	-6,359.4	-7,076.0	-1,172.3	-5,517.2	-6,884.3
Percent Change from No Action (%)	0.0	-5.0	-3.7	-4.1	-0.7	-3.2	-4.0

Channel Catfish
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	634,215.1	617,946.2	622,977.6	621,286.2	633,202.1	625,577.7	621,153.2
Difference Gained or Lost from No Action (ft^2)	0.0	-16,268.9	-11,237.5	-12,928.9	-1,013.0	-8,637.4	-13,061.9
Percent Change from No Action (%)	0.0	-2.6	-1.8	-2.0	-0.2	-1.4	-2.1

Rio Grande at Bernalillo Study Site –

Rio Grande Silvery Minnow
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	96,469.1	100,733.2	99,594.0	99,744.3	95,998.5	97,464.3	99,754.9
Difference Gained or Lost from No Action (ft^2)	0.0	4,264.1	3,124.9	3,275.2	-470.6	995.3	3,285.8
Percent Change from No Action (%)	0.0	4.4	3.2	3.4	-0.5	1.0	3.4

Rio Grande Silvery Minnow
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	127,887.4	130,374.4	129,905.7	129,823.0	127,033.4	127,774.5	129,884.0
Difference Gained or Lost from No Action (ft^2)	0.0	2,487.0	2,018.3	1,935.6	-854.0	-112.9	1,996.6
Percent Change from No Action (%)	0.0	1.9	1.6	1.5	-0.7	-0.1	1.6

Flathead Chub
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	46,101.0	52,859.0	50,844.4	51,337.7	46,168.0	48,916.7	51,232.0
Difference Gained or Lost from No Action (ft^2)	0.0	6,758.0	4,743.5	5,236.7	67.0	2,815.7	5,131.0
Percent Change from No Action (%)	0.0	14.7	10.3	11.4	0.1	6.1	11.1

Flathead Chub
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	77,368.4	80,729.8	79,955.0	80,083.0	77,226.4	78,945.7	79,991.0
Difference Gained or Lost from No Action (ft^2)	0.0	3,361.4	2,586.6	2,714.6	-142.0	1,577.3	2,622.6
Percent Change from No Action (%)	0.0	4.3	3.3	3.5	-0.2	2.0	3.4

Longnose Dace
Juvenile

	No Action	Alternative B-3	Alternative D-3	Alternative E-3	Alternative I-1	Alternative I-2	Alternative I-3
Mean Habitat (ft^2)	28,206.6	30,853.2	29,851.0	30,074.3	28,193.0	28,619.2	30,026.3
Difference Gained or Lost from No Action (ft^2)	0.0	2,646.6	1,644.4	1,867.7	-13.6	412.6	1,819.7
Percent Change from No Action (%)	0.0	9.4	5.8	6.6	0.0	1.5	6.5

Longnose Dace
Adult

	No Action	Alternative B-3	Alternative D-3	Alternative E-3	Alternative I-1	Alternative I-2	Alternative I-3
Mean Habitat (ft^2)	99,377.3	95,442.1	96,838.9	96,316.0	98,685.1	96,880.2	96,334.3
Difference Gained or Lost from No Action (ft^2)	0.0	-3,935.2	-2,538.4	-3,061.2	-692.2	-2,497.1	-3,043.0
Percent Change from No Action (%)	0.0	-4.0	-2.6	-3.1	-0.7	-2.5	-3.1

River Carpsucker
Juvenile

	No Action	Alternative B-3	Alternative D-3	Alternative E-3	Alternative I-1	Alternative I-2	Alternative I-3
Mean Habitat (ft^2)	41,947.5	47,617.1	45,984.6	46,386.4	41,990.4	44,440.9	46,296.3
Difference Gained or Lost from No Action (ft^2)	0.0	5,669.6	4,037.0	4,438.8	42.9	2,493.3	4,348.8
Percent Change from No Action (%)	0.0	13.5	9.6	10.6	0.1	5.9	10.4

Channel Catfish
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	72,554.6	76,284.9	74,873.5	75,100.5	72,199.8	72,370.7	75,118.8
Difference Gained or Lost from No Action (ft^2)	0.0	3,730.3	2,318.9	2,546.0	-354.7	-183.8	2,564.2
Percent Change from No Action (%)	0.0	5.1	3.2	3.5	-0.5	-0.3	3.5

Channel Catfish
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	254,589.8	251,668.7	252,806.9	252,182.6	253,310.6	251,221.8	252,111.5
Difference Gained or Lost from No Action (ft^2)	0.0	-2,921.1	-1,782.9	-2,407.1	-1,279.2	-3,367.9	-2,478.3
Percent Change from No Action (%)	0.0	-1.1	-0.7	-0.9	-0.5	-1.3	-1.0

1.9.4.2 Rio Grande at Central Avenue Bridge Study Site

Rio Grande Silvery Minnow
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	527,121.1	506,084.9	513,585.9	510,543.2	523,396.0	514,096.8	510,322.1
Difference Gained or Lost from No Action (ft^2)	0.0	-21,036.2	-13,535.2	-16,577.8	-3,725.0	-13,024.3	-16,799.0
Percent Change from No Action (%)	0.0	-4.0	-2.6	-3.1	-0.7	-2.5	-3.2

Rio Grande Silvery Minnow
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	670,380.1	648,777.2	657,102.5	653,871.0	666,727.1	658,818.9	653,253.3
Difference Gained or Lost from No Action (ft^2)	0.0	-21,602.9	-13,277.7	-16,509.1	-3,653.1	-11,561.2	-17,126.8
Percent Change from No Action (%)	0.0	-3.2	-2.0	-2.5	-0.5	-1.7	-2.6

Flathead Chub
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	264,950.4	254,667.9	258,566.7	256,777.1	262,462.6	257,984.3	256,937.4
Difference Gained or Lost from No Action (ft^2)	0.0	-10,282.5	-6,383.7	-8,173.3	-2,487.8	-6,966.1	-8,013.0
Percent Change from No Action (%)	0.0	-3.9	-2.4	-3.1	-0.9	-2.6	-3.0

Flathead Chub
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	284,589.4	274,061.5	278,013.8	276,330.2	281,798.9	277,247.4	276,352.8
Difference Gained or Lost from No Action (ft^2)	0.0	-10,527.8	-6,575.5	-8,259.2	-2,790.5	-7,341.9	-8,236.6
Percent Change from No Action (%)	0.0	-3.7	-2.3	-2.9	-1.0	-2.6	-2.9

Longnose Dace
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	104,723.9	101,743.3	102,797.1	102,152.9	104,270.0	102,841.4	102,264.7
Difference Gained or Lost from No Action (ft^2)	0.0	-2,980.6	-1,926.8	-2,571.0	-453.9	-1,882.5	-2,459.2
Percent Change from No Action (%)	0.0	-2.8	-1.8	-2.5	-0.4	-1.8	-2.3

<u>Longnose Dace</u>
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	163,690.9	157,248.6	159,238.1	158,642.2	163,550.3	160,297.3	158,275.9
Difference Gained or Lost from No Action (ft^2)	0.0	-6,442.2	-4,452.8	-5,048.6	-140.5	-3,393.6	-5,415.0
Percent Change from No Action (%)	0.0	-3.9	-2.7	-3.1	-0.1	-2.1	-3.3

<u>River Carpsucker</u>
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	235,795.9	227,824.7	230,864.9	229,440.7	233,635.9	230,432.9	229,528.6
Difference Gained or Lost from No Action (ft^2)	0.0	-7,971.3	-4,931.1	-6,355.2	-2,160.1	-5,363.1	-6,267.3
Percent Change from No Action (%)	0.0	-3.4	-2.1	-2.7	-0.9	-2.3	-2.7

<u>Channel Catfish</u>
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	478,576.2	461,388.5	468,245.9	465,336.4	474,254.1	467,453.6	465,303.7
Difference Gained or Lost from No Action (ft^2)	0.0	-17,187.7	-10,330.3	-13,239.8	-4,322.1	-11,122.6	-13,272.4
Percent Change from No Action (%)	0.0	-3.6	-2.2	-2.8	-0.9	-2.3	-2.8

Channel Catfish
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	998,606.4	998,028.5	999,024.7	997,795.3	997,850.5	998,947.6	996,200.1
Difference Gained or Lost from No Action (ft^2)	0.0	-577.9	418.3	-811.1	-755.8	341.2	-2,406.3
Percent Change from No Action (%)	0.0	-0.1	0.0	-0.1	-0.1	0.0	-0.2

1.9.4.3 Rio Grande Downstream of US 60 Bridge near Bernardo Study Site

Rio Grande Silvery Minnow
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	342,267.0	338,800.6	337,577.7	338,477.7	338,847.1	335,048.7	337,494.5
Difference Gained or Lost from No Action (ft^2)	0.0	-3,466.3	-4,689.3	-3,789.2	-3,419.9	-7,218.2	-4,772.5
Percent Change from No Action (%)	0.0	-1.0	-1.4	-1.1	-1.0	-2.1	-1.4

Rio Grande Silvery Minnow
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	144,349.2	160,600.4	153,510.3	155,814.8	146,241.1	151,764.2	155,357.3
Difference Gained or Lost from No Action (ft^2)	0.0	16,251.2	9,161.0	11,465.6	1,891.9	7,414.9	11,008.1
Percent Change from No Action (%)	0.0	11.3	6.3	7.9	1.3	5.1	7.6

Flathead Chub
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	127,044.2	130,717.6	128,700.6	129,502.0	126,030.1	127,097.5	129,130.9
Difference Gained or Lost from No Action (ft^2)	0.0	3,673.5	1,656.4	2,457.8	-1,014.1	53.3	2,086.8
Percent Change from No Action (%)	0.0	2.9	1.3	1.9	-0.8	0.0	1.6

Flathead Chub
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	698,816.9	709,889.3	701,192.0	704,471.3	698,889.9	701,793.4	702,285.1
Difference Gained or Lost from No Action (ft^2)	0.0	11,072.4	2,375.1	5,654.4	73.0	2,976.5	3,468.2
Percent Change from No Action (%)	0.0	1.6	0.3	0.8	0.0	0.4	0.5

Longnose Dace
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	55,186.3	56,810.0	55,799.4	56,185.4	55,182.6	55,673.7	55,989.4
Difference Gained or Lost from No Action (ft^2)	0.0	1,623.6	613.1	999.1	-3.7	487.3	803.1
Percent Change from No Action (%)	0.0	2.9	1.1	1.8	0.0	0.9	1.5

Longnose Dace
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	300,525.6	293,367.0	292,871.0	293,284.4	299,985.7	295,225.2	292,370.2
Difference Gained or Lost from No Action (ft^2)	0.0	-7,158.6	-7,654.6	-7,241.2	-539.9	-5,300.3	-8,155.4
Percent Change from No Action (%)	0.0	-2.4	-2.5	-2.4	-0.2	-1.8	-2.7

River Carpsucker
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	322,772.1	322,532.1	320,735.1	321,738.9	319,833.7	318,255.7	320,811.3
Difference Gained or Lost from No Action (ft^2)	0.0	-240.0	-2,037.0	-1,033.2	-2,938.4	-4,516.4	-1,960.8
Percent Change from No Action (%)	0.0	-0.1	-0.6	-0.3	-0.9	-1.4	-0.6

Channel Catfish
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	250,963.8	251,727.5	249,951.2	250,855.3	248,330.7	247,379.9	250,166.1
Difference Gained or Lost from No Action (ft^2)	0.0	763.7	-1,012.6	-108.4	-2,633.1	-3,583.9	-797.7
Percent Change from No Action (%)	0.0	0.3	-0.4	0.0	-1.0	-1.4	-0.3

Channel Catfish

Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	721,625.5	735,096.0	725,688.2	729,208.8	721,873.2	725,417.0	727,069.5
Difference Gained or Lost from No Action (ft^2)	0.0	13,470.5	4,062.7	7,583.4	247.8	3,791.5	5,444.1
Percent Change from No Action (%)	0.0	1.9	0.6	1.1	0.0	0.5	0.8

1.9.4.4 Rio Grande just Downstream of North Boundary of Bosque del Apache National Wildlife Refuge Study Site

Rio Grande Silvery Minnow
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	364,526.9	250,278.5	251,144.1	251,578.9	307,365.2	275,018.8	250,954.1
Difference Gained or Lost from No Action (ft^2)	0.0	-114,248.5	-113,382.8	-112,948.1	-57,161.8	-89,508.2	-113,572.9
Percent Change from No Action (%)	0.0	-31.3	-31.1	-31.0	-15.7	-24.6	-31.2

Rio Grande Silvery Minnow
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	440,221.9	304,595.3	305,494.5	306,051.9	375,386.1	335,219.0	305,267.4
Difference Gained or Lost from No Action (ft^2)	0.0	-135,626.6	-134,727.5	-134,170.0	-64,835.8	-105,002.9	-134,954.5
Percent Change from No Action (%)	0.0	-30.8	-30.6	-30.5	-14.7	-23.9	-30.7

Flathead Chub
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	233,007.3	139,822.4	140,633.6	140,887.4	186,722.2	159,373.0	140,580.0
Difference Gained or Lost from No Action (ft^2)	0.0	-93,184.8	-92,373.7	-92,119.9	-46,285.1	-73,634.2	-92,427.3
Percent Change from No Action (%)	0.0	-40.0	-39.6	-39.5	-19.9	-31.6	-39.7

Flathead Chub
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	286,909.2	154,882.0	156,158.1	156,356.2	224,680.3	184,047.1	156,049.9
Difference Gained or Lost from No Action (ft^2)	0.0	-132,027.1	-130,751.0	-130,553.0	-62,228.8	-102,862.1	-130,859.2
Percent Change from No Action (%)	0.0	-46.0	-45.6	-45.5	-21.7	-35.9	-45.6

Longnose Dace
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	101,067.7	40,355.4	40,857.5	40,990.7	73,637.4	53,168.2	40,937.0
Difference Gained or Lost from No Action (ft^2)	0.0	-60,712.4	-60,210.2	-60,077.0	-27,430.4	-47,899.5	-60,130.7
Percent Change from No Action (%)	0.0	-60.1	-59.6	-59.4	-27.1	-47.4	-59.5

<u>*Longnose Dace*</u>
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	200,863.7	85,096.6	86,603.4	86,488.1	146,689.2	112,477.7	86,327.9
Difference Gained or Lost from No Action (ft^2)	0.0	-115,767.0	-114,260.3	-114,375.6	-54,174.4	-88,386.0	-114,535.7
Percent Change from No Action (%)	0.0	-57.6	-56.9	-56.9	-27.0	-44.0	-57.0

<u>*River Carpsucker*</u>
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	216,021.8	133,155.8	133,727.0	134,024.5	176,482.5	150,557.4	133,725.6
Difference Gained or Lost from No Action (ft^2)	0.0	-82,866.0	-82,294.7	-81,997.3	-39,539.3	-65,464.4	-82,296.2
Percent Change from No Action (%)	0.0	-38.4	-38.1	-38.0	-18.3	-30.3	-38.1

<u>*Channel Catfish*</u>
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	323,608.9	231,388.2	231,923.9	232,388.3	278,043.3	251,103.4	231,799.4
Difference Gained or Lost from No Action (ft^2)	0.0	-92,220.8	-91,685.0	-91,220.6	-45,565.6	-72,505.6	-91,809.5
Percent Change from No Action (%)	0.0	-28.5	-28.3	-28.2	-14.1	-22.4	-28.4

Channel Catfish
Adult

	No Action	Alternative B-3	Alternative D-3	Alternative E-3	Alternative I-1	Alternative I-2	Alternative I-3
Mean Habitat (ft^2)	672,004.2	364,374.5	367,511.1	367,835.2	531,637.3	436,265.2	367,008.2
Difference Gained or Lost from No Action (ft^2)	0.0	-307,629.8	-304,493.2	-304,169.0	-140,366.9	-235,739.0	-304,996.0
Percent Change from No Action (%)	0.0	-45.8	-45.3	-45.3	-20.9	-35.1	-45.4

1.9.4.5 Rio Grande Below the San Marcial Railroad Bridge Study Site

Rio Grande Silvery Minnow
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	86,507.9	109,878.5	108,372.1	108,974.2	99,399.4	102,121.9	108,614.1
Difference Gained or Lost from No Action (ft^2)	0.0	23,370.6	21,864.2	22,466.3	12,891.5	15,614.0	22,106.2
Percent Change from No Action (%)	0.0	27.0	25.3	26.0	14.9	18.0	25.6

Rio Grande Silvery Minnow
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	120,951.6	148,541.5	146,257.5	147,153.8	135,048.0	137,932.9	146,627.3
Difference Gained or Lost from No Action (ft^2)	0.0	27,589.9	25,305.9	26,202.2	14,096.4	16,981.3	25,675.7
Percent Change from No Action (%)	0.0	22.8	20.9	21.7	11.7	14.0	21.2

Flathead Chub
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	46,877.3	59,155.6	58,421.7	58,724.7	53,249.6	54,918.0	58,533.9
Difference Gained or Lost from No Action (ft^2)	0.0	12,278.3	11,544.4	11,847.4	6,372.3	8,040.7	11,656.6
Percent Change from No Action (%)	0.0	26.2	24.6	25.3	13.6	17.2	24.9

Flathead Chub
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	68,259.3	76,691.3	75,423.5	75,919.7	73,679.9	72,004.3	75,657.9
Difference Gained or Lost from No Action (ft^2)	0.0	8,432.0	7,164.3	7,660.4	5,420.6	3,745.1	7,398.7
Percent Change from No Action (%)	0.0	12.4	10.5	11.2	7.9	5.5	10.8

Longnose Dace
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	14,645.7	17,055.1	16,593.7	16,736.2	16,708.0	15,052.3	16,670.6
Difference Gained or Lost from No Action (ft^2)	0.0	2,409.4	1,947.9	2,090.5	2,062.3	406.5	2,024.8
Percent Change from No Action (%)	0.0	16.5	13.3	14.3	14.1	2.8	13.8

Longnose Dace
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	43,410.3	32,191.5	30,997.1	31,445.1	40,112.1	31,294.8	31,322.9
Difference Gained or Lost from No Action (ft^2)	0.0	-11,218.8	-12,413.2	-11,965.2	-3,298.2	-12,115.5	-12,087.4
Percent Change from No Action (%)	0.0	-25.8	-28.6	-27.6	-7.6	-27.9	-27.8

River Carpsucker
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	52,760.5	68,014.6	67,306.4	67,608.9	59,893.4	63,449.3	67,376.7
Difference Gained or Lost from No Action (ft^2)	0.0	15,254.1	14,545.9	14,848.4	7,132.8	10,688.8	14,616.2
Percent Change from No Action (%)	0.0	28.9	27.6	28.1	13.5	20.3	27.7

Channel Catfish
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	93,906.3	123,037.5	121,412.5	122,054.5	107,473.8	113,264.9	121,627.6
Difference Gained or Lost from No Action (ft^2)	0.0	29,131.2	27,506.2	28,148.2	13,567.5	19,358.6	27,721.3
Percent Change from No Action (%)	0.0	31.0	29.3	30.0	14.4	20.6	29.5

Channel Catfish

Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	280,477.5	242,802.0	238,269.6	240,243.5	261,909.3	237,799.8	239,292.1
Difference Gained or Lost from No Action (ft^2)	0.0	-37,675.4	-42,207.8	-40,233.9	-18,568.2	-42,677.7	-41,185.4
Percent Change from No Action (%)	0.0	-13.4	-15.0	-14.3	-6.6	-15.2	-14.7

1.9.4.6 Rio Chama Downstream of Abiquiu Dam –

Brown Trout
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	328,748.7	325,101.8	327,012.4	326,051.5	331,059.4	329,050.7	325,808.2
Difference Gained or Lost from No Action (ft^2)	0.0	-3,646.9	-1,736.4	-2,697.2	2,310.7	302.0	-2,940.5
Percent Change from No Action (%)	0.0	-1.1	-0.5	-0.8	0.7	0.1	-0.9

Brown Trout
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	264,620.4	261,850.6	262,981.8	262,276.1	266,358.5	264,949.6	262,002.2
Difference Gained or Lost from No Action (ft^2)	0.0	-2,769.8	-1,638.6	-2,344.3	1,738.2	329.2	-2,618.2
Percent Change from No Action (%)	0.0	-1.0	-0.6	-0.9	0.7	0.1	-1.0

Flathead Chub
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	26,639.9	27,271.4	28,136.3	27,928.0	27,176.3	27,568.0	28,022.7
Difference Gained or Lost from No Action (ft^2)	0.0	631.5	1,496.3	1,288.1	536.4	928.0	1,382.7
Percent Change from No Action (%)	0.0	2.4	5.6	4.8	2.0	3.5	5.1

Flathead Chub
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	59,929.6	60,250.5	62,314.2	61,776.6	60,762.1	61,817.3	61,885.3
Difference Gained or Lost from No Action (ft^2)	0.0	320.9	2,384.6	1,847.0	832.5	1,887.7	1,955.7
Percent Change from No Action (%)	0.0	0.5	4.0	3.1	1.4	3.1	3.2

Longnose Dace
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	13,944.8	14,329.9	14,863.4	14,742.5	14,237.6	14,541.9	14,808.1
Difference Gained or Lost from No Action (ft^2)	0.0	385.2	918.6	797.8	292.8	597.2	863.3
Percent Change from No Action (%)	0.0	2.8	6.6	5.7	2.1	4.3	6.2

Longnose Dace
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	100,795.8	101,936.6	105,672.1	104,780.9	102,347.7	104,981.4	104,854.3
Difference Gained or Lost from No Action (ft^2)	0.0	1,140.9	4,876.4	3,985.2	1,551.9	4,185.7	4,058.5
Percent Change from No Action (%)	0.0	1.1	4.8	4.0	1.5	4.2	4.0

River Carpsucker
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	32,906.4	32,611.7	32,600.5	32,550.9	33,281.4	32,250.5	32,576.0
Difference Gained or Lost from No Action (ft^2)	0.0	-294.7	-305.9	-355.5	375.0	-655.9	-330.4
Percent Change from No Action (%)	0.0	-0.9	-0.9	-1.1	1.1	-2.0	-1.0

Channel Catfish
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	65,643.1	65,588.3	68,015.0	67,464.3	65,952.0	67,286.9	67,572.8
Difference Gained or Lost from No Action (ft^2)	0.0	-54.8	2,371.9	1,821.2	309.0	1,643.9	1,929.7
Percent Change from No Action (%)	0.0	-0.1	3.6	2.8	0.5	2.5	2.9

Channel Catfish

Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	186,239.6	186,800.4	192,444.9	191,011.1	188,172.7	191,940.5	191,084.0
Difference Gained or Lost from No Action (ft^2)	0.0	560.8	6,205.3	4,771.4	1,933.0	5,700.8	4,844.4
Percent Change from No Action (%)	0.0	0.3	3.3	2.6	1.0	3.1	2.6

1.9.4.7 Rio Chama Upstream of New Highway 285 Bridge

Rio Grande Silvery Minnow
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	44,592.8	41,176.4	43,113.2	42,715.3	43,294.2	42,758.1	42,838.8
Difference Gained or Lost from No Action (ft^2)	0.0	-3,416.3	-1,479.6	-1,877.5	-1,298.6	-1,834.7	-1,753.9
Percent Change from No Action (%)	0.0	-7.7	-3.3	-4.2	-2.9	-4.1	-3.9

Rio Grande Silvery Minnow
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	65,460.3	60,865.0	63,295.4	62,865.3	63,750.1	62,692.5	62,978.4
Difference Gained or Lost from No Action (ft^2)	0.0	-4,595.3	-2,164.9	-2,595.0	-1,710.2	-2,767.8	-2,481.9
Percent Change from No Action (%)	0.0	-7.0	-3.3	-4.0	-2.6	-4.2	-3.8

<u>Flathead Chub</u>
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	18,573.2	17,540.5	18,283.9	18,048.3	18,148.7	17,979.7	18,158.8
Difference Gained or Lost from No Action (ft^2)	0.0	-1,032.7	-289.2	-524.8	-424.4	-593.5	-414.4
Percent Change from No Action (%)	0.0	-5.6	-1.6	-2.8	-2.3	-3.2	-2.2

<u>Flathead Chub</u>
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	53,494.1	51,023.4	52,567.6	52,180.8	52,778.9	51,962.9	52,284.8
Difference Gained or Lost from No Action (ft^2)	0.0	-2,470.8	-926.6	-1,313.3	-715.2	-1,531.2	-1,209.4
Percent Change from No Action (%)	0.0	-4.6	-1.7	-2.5	-1.3	-2.9	-2.3

<u>Longnose Dace</u>
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	12,240.2	11,770.5	12,090.0	11,971.3	12,135.7	11,956.2	12,009.5
Difference Gained or Lost from No Action (ft^2)	0.0	-469.6	-150.2	-268.8	-104.4	-284.0	-230.6
Percent Change from No Action (%)	0.0	-3.8	-1.2	-2.2	-0.9	-2.3	-1.9

Longnose Dace
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	88,080.1	84,548.0	86,510.8	86,080.6	87,566.9	86,065.7	86,067.3
Difference Gained or Lost from No Action (ft^2)	0.0	-3,532.1	-1,569.3	-1,999.5	-513.2	-2,014.4	-2,012.8
Percent Change from No Action (%)	0.0	-4.0	-1.8	-2.3	-0.6	-2.3	-2.3

River Carpsucker
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	14,092.2	13,506.0	13,971.5	13,817.7	13,807.7	13,659.5	13,909.5
Difference Gained or Lost from No Action (ft^2)	0.0	-586.2	-120.7	-274.5	-284.5	-432.7	-182.7
Percent Change from No Action (%)	0.0	-4.2	-0.9	-1.9	-2.0	-3.1	-1.3

Channel Catfish
Juvenile

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	33,962.2	31,906.3	33,130.3	32,865.5	33,021.1	32,780.8	32,987.4
Difference Gained or Lost from No Action (ft^2)	0.0	-2,055.9	-831.9	-1,096.7	-941.1	-1,181.4	-974.9
Percent Change from No Action (%)	0.0	-6.1	-2.4	-3.2	-2.8	-3.5	-2.9

<u>*Channel Catfish*</u>
Adult

	No Action	*Alternative B-3*	*Alternative D-3*	*Alternative E-3*	*Alternative I-1*	*Alternative I-2*	*Alternative I-3*
Mean Habitat (ft^2)	164,817.6	160,909.3	161,755.2	161,607.8	164,468.5	160,199.3	161,644.8
Difference Gained or Lost from No Action (ft^2)	0.0	-3,908.3	-3,062.4	-3,209.8	-349.1	-4,618.3	-3,172.8
Percent Change from No Action (%)	0.0	-2.4	-1.9	-1.9	-0.2	-2.8	-1.9

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APPENDIX L
BIOLOGICAL RESOURCES

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1.0 INTRODUCTION

This Biological Technical Report provides documentation of investigations into the current condition of aquatic ecological systems and riparian ecosystems, wetlands, and federally-listed endangered species of the Upper Rio Grande Basin, and the effects of proposed changes to federal water operations on those biological resources. It consists of both existing biological data and original studies conducted to expand the scientific knowledge of biological resources, and analyze the effects of proposed changes in the Upper Rio Grande Water Operations Review and Environmental Impact Statement (Project). The Project is a cooperative process involving multi-disciplinary and multi-agency effort to develop integrated water operations with the goal of improving basin-wide hydrology for ecological function as well as multiple human uses.

Ecological systems in the Rio Grande Basin have evolved according to the primary influences of Rio Grande Basin climatology, hydrology and geomorphology. Human uses in the Rio Grande Basin have gradually changed the hydrology of the Basin over the past 100 years, resulting in significant changes to both the aquatic and riparian ecosystems. Water management in the upper Rio Grande Basin evolved over decades, the result of separate and distinct authorizing legislation and accumulated policies of different agencies with differing missions. Coordination among these agencies became especially critical in the mid-1990s with the designation of two endangered species known to occur in the Central and San Acacia sections of the river system: the Southwestern willow flycatcher (*Empidonax traillii estimus*) and the Rio Grande silvery minnow (*Hybognathus amarus*).

The Project developed new knowledge and more effective tools including the long-term planning version of the Upper Rio Grande Water Operations Model (URGWOM) and a specific set of written operating rules and coordination procedures (the Preferred Action) as outcomes of this project. The multi-agency planning process identified improvements to ecological function as a high priority for the Project. The final phase of the Project evaluated potential adverse effects of the chosen alternative on the resources reviewed in this EIS, including those ecological processes and species identified in this Biological Technical Report.

In order to evaluate problems and flexibilities in the system and the relative effects of proposed changes in water operations, an improved knowledge base of baseline ecological resources was developed, along with improved analytical tools, presented in Section 2 of the Technical Report. These stand as a foundation for future research, planning, and management. Several models and analysis systems were used in the evaluation of alternatives. Key tools for evaluating the future effects of proposed alternative water operations are described in Sections 3 of this Technical Report, along with the results of the analysis. In addition, to assist readers in a full understanding of the Project, a list of abbreviations, acronyms, and an abbreviated list of technical terms are conveniently located on the inside cover of this document. Appendix C presents a full glossary of technical terms and acronyms.

1.1 *Upper Rio Grande Study Area*

Located at the western edge of the Great Plains and 1,885 miles (3,150 km) in length, the Rio Grande is the fifth longest river in North America. It runs from its headwaters in the San Juan Mountains of southern Colorado to its terminus in the Gulf of Mexico (Williams (1986). Several tributaries contribute to the flow patterns of the Rio Grande in the Upper Rio Grande including the Conejos River in southern Colorado, the Rio Chama in northern New Mexico, the Jemez River in north-central New Mexico, and the Rio Puerco in central New Mexico. These rivers are fed primarily by melting snow pack from high elevations in northern New Mexico and southern Colorado and by seasonal precipitation.

As described in Chapter 1 of the EIS, and in Appendix H, Geomorphology, the Upper Rio Grande Basin was divided into five River Sections based on geomorphic reaches and hydrologic influences.

- The Northern Section includes the area from Alamosa, Colorado to the Confluence with the Rio Chama at San Juan Pueblo in New Mexico. It includes the Closed Basin Project in Colorado, but consists of largely unregulated flows in New Mexico. This includes geomorphic Reaches 1-4.
- The Rio Chama Section includes the entire Rio Chama from Heron Reservoir to the confluence with the Rio Grande, plus the Rio Grande from the confluence with Rio Chama to Cochiti Reservoir. This section is highly regulated and influenced by the combined operations of Heron, El Vado, Abiquiu, and Cochiti reservoirs. This includes geomorphic Reaches 5-10.
- The Central Section includes the Rio Grande floodplain and channel between Cochiti Dam and the confluence of the Rio Puerco south of Socorro, New Mexico. This section is regulated by flood control operations at Cochiti and influenced by rules at several other facilities, including Abiquiu and Elephant Butte dams. This section includes geomorphic Reaches 10-13.
- The San Acacia Section includes the floodplain and channel of the Rio Grande between the confluences with the Rio Puerco to Elephant Butte Dam. This section receives unregulated flows from the Rio Puerco, regulated flows on the main-stem of the Rio Grande, and potential diversions at the Low Flow Conveyance Channel. This includes geomorphic Reach 14.
- The Southern Section includes the areas between Elephant Butte Reservoir in New Mexico, and Fort Quitman, Texas. This section is highly regulated at Elephant Butte and Caballo reservoirs and the river has been highly modified and canalized. This includes geomorphic Reaches 15–17.

The Upper Rio Grande Water Operations Review and EIS identified flexibilities and considered the potential effects of changing operations at five facilities on the Rio Grande and Rio Chama, as described in Section 1.1. The potential for biological effects from changing operations was limited to those areas along the Rio Chama and Rio Grande subject to changes in hydrology under the alternatives considered. Specifically, the areas considered in the study of biological effects include the floodplain and channel of the Rio Chama from Heron Dam to the confluence of the Rio Grande, but excluding El Vado reservoir. On the Rio Grande, the areas studied include the floodplain and channel from San Juan Pueblo south to Elephant Butte Reservoir. Therefore, the Northern Section and the Southern sections were considered in the evaluation of the biological baseline conditions, but eliminated from further analysis of impacts.

1.2 Purpose and Organization of the Biological Technical Report

The biological importance and sensitivity of the Upper Rio Grande is directly related to surface water hydrology in an otherwise arid region. In arid regions, the presence of surface flows originating hundreds of miles away can exert fundamental control over the composition and structure of biological communities and the abundance and richness of all forms of life. New Mexico's riparian areas are the most species-rich in the state. The continual presence of water and the complex structural components of riparian zones also support the highest percentage of breeding species than any other habitat type. Due to the Project Area's north-south orientation and the fact that the Rio Grande is one of five major migratory corridors in North America, the area hosts a large and varied mix of neotropical avian species. Lastly, the project area contains several species that federally listed as Threatened or Endangered, and thus receive protection under the Endangered Species Act (USFWS 2003). Changing water operations of the Upper Rio Grande will, by nature, affect biological resources downstream of dams and other facilities. The timing, duration, and long-term availability of water are key factors in riparian and aquatic ecosystems that will be explored in this Technical Report.

Chapter 1 has provided an overview of the Upper Rio Grande Water Operations Review and EIS process, as well as a description of the study area potentially affected by changes in water operations and management.

In Chapter 2, each biological resource within the Project Area is individually characterized, beginning with a description of specific methods utilized to establish a baseline for each resource. The methods used to characterize the current condition of existing resources are described quantitatively and qualitatively and the biological trends related to hydrological change are characterized as well. Some resources considered to be fundamental to the biological ecosystem, such as aquatic and riparian habitats, required extensive original studies. The methods and results of these studies are provided.

The current biological conditions and trends form the foundation for the impact analyses presented in Chapter 3 of this Technical Report. Chapter 3 follows the same organization, starting with the methods used to determine potential impacts and completing with a detailed description of each Alternative's potential impacts ─ either negative or positive ─ on pertinent biological resources.

Since future water operations of the Upper Rio Grande may involve adaptive management, Chapter 4 provides biological recommendations for the resources considered most vulnerable to ecological perturbation from water operations.

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2.0 EXISTING BIOLOGICAL CONDITIONS

2.1 *General Methods*

Chapter Two of the Biological Technical Report describes current conditions and trends in aquatic and riparian ecosystems in Upper Rio Grande study area, but focuses particularly on those areas most likely to be affected by proposed changes in water operations in the Rio Chama, Central, and San Acacia Sections.

In this chapter, existing data and information available in scientific literature are presented, as they are pertinent to the baseline biological resources, resource trends, and factors relevant to the proposed changes in water operations. An aquatic habitat model and a comprehensive vegetation survey were developed specifically for the Project to provide critical baseline information on biological resources in the Project Area. The Geographic Information System (GIS), a basin-wide system for geospatial analysis, was used for data integration across all biological resources and for referencing data points to specific geographic locations. GIS was also used as the base for managing and sharing data throughout the lifecycle of this EIS for data collection, organization, evaluation, analysis, and synthesis.

2.2 *Aquatic Ecosystems*

2.2.1 *Methods*

2.2.1.1 Modeling Baseline Aquatic Habitat

The Upper Rio Grande Water Operations Model (URGWOM) provides basic water operations functions and codifies operating rules and existing operation criteria. This allows for water accounting and unrefined evaluations of water operation alternatives on a broad scale throughout the basin. URGWOM functions as a routing and accounting model using reservoirs and pertinent gauging stations as nodes. It will be used to simulate reservoir elevation and river discharges at key nodes in the basin over a hydrologic period determined to be representative of the highly variable nature of the Rio Grande.

Sub-models utilize discharge outputs from URGWOM and allow more detailed analyses and scenario-building between the nodes of the main model. The aquatic habitat sub-model is based on two-dimensional discharge (flow and depth) hydraulic models and allows integration of site-specific ecological parameters either in the model itself or through interfacing with GIS data.

2.2.1.2 Riverine Habitat Characterization Methods

In conjunction with the 17 specific study reaches identified for URGWOM, 8 sites (six on the Rio Grande and two on the Rio Chama) representing geomorphologic variation in the middle Rio Grande basin have been chosen for the aquatic habitat model (Bohannon-Huston et al. 2004). Each reach was approximately 5- to 7-times the channel width at the specific location. GPS and discharge measurement equipment was used to simultaneously collect georeferenced topographic and hydrologic data generated from the two-dimensional hydraulic model. Two-dimensional hydraulic modeling and the Aquatic Habitat Model were used to finalize a habitat-flow model that predicts surface area of available aquatic habitat based on depth and velocity distributions for all middle Rio Grande and Rio Chama reaches studied (**Figure L-2.1**).

Hydraulic model simulations were conducted for up to 10 flows with the Surface Water Modeling System (SMS 8.0) and outputs prepared in a format for use in GIS to input into the Habitat-Flow Model.

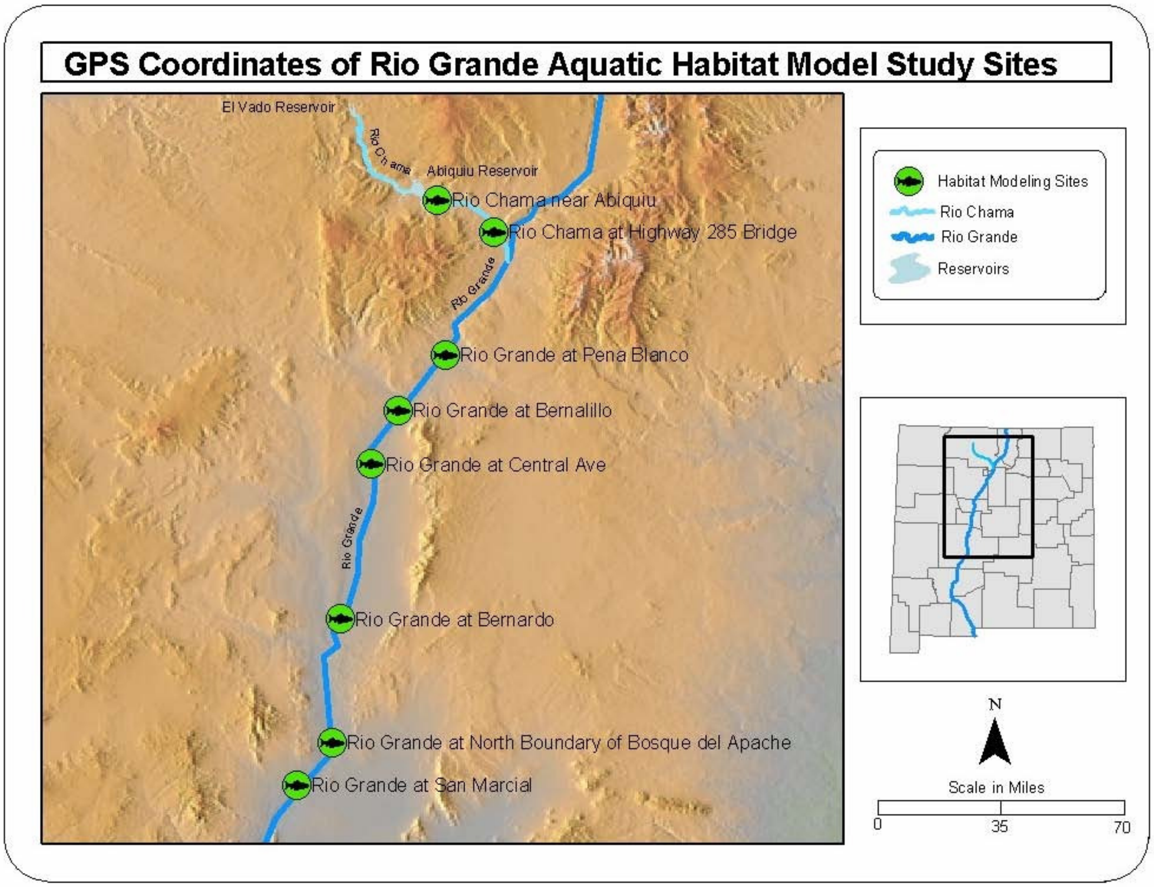


Figure L-2.1 Study areas for aquatic resources.

2.2.2 *Upper Rio Grande Riverine Resources*

2.2.2.1 Riverine Habitat

Riverine habitat is the wetted area within a river channel where flowing water is discharged and includes both the surface and subsurface aquatic zones. The Project's proposed change in the quantity and quality of available riverine habitat is the factor most likely to affect species in the Rio Grande.

Limited studies have been conducted to determine the habitat needs for Rio Grande fishes. Historically the Rio Grande supported over 21 native species of fish of which over 1/3 have been extirpated or are extinct (Propst 1999). Dudley and Platania (1997) found five species to be evenly represented in their samples: native red shiner, Rio Grande silvery minnow (RGSM), flathead chub, and longnose dace, and the introduced white sucker that accounted for 77.7% of the catch. In this study, habitats collectively occupied by all species are characterized by shallow depth, low water velocity, and small substrata. The majority of individuals occupied depths <30 cm, in water velocities < 10 cm/s and with substrata dominated by silt. The occupied depths and velocities differed significantly ($p<0.01$) from available habitats. Fish were most frequently caught in low-velocity habitats such as backwaters (17.2%), debris piles (34.0 %) and pools (36.0%). This occurrence represents a marked contrast to the high abundance of deep and high-velocity habitats that dominated both of the study sites in this study.

The availability of low-velocity habitats may also be a limiting factor for endangered species present in the Project Area. In the Rio Grande, the RGSM is the only state and federally protected species; however, the Rio Grande sucker and the Rio Grande chub may warrant state protection (Propst 1999). The RGSM was historically one of the most widespread fishes in the Rio Grande basin (FR 1993, Bestgen and Propst 1996), but now only occurs from Cochiti dam downstream to within the vicinity of Elephant Butte Reservoir, an area designated as critical habitat for the species. Dudley and Platania (1997) evaluated the habitat use for the Rio Grande silvery minnow (*Hybognathus amarus*) and the associated fish community and determined that the low-velocity habitats described above are preferred by this species.

The effects of hydrologic and physical modifications on the aquatic ecosystem and associated organisms are difficult to quantify because of the lack of comparable historical data. Surveys of the fish fauna from the Rio Grande and Rio Chama as well as the Rio Jemez began in the early 1980's. Collectively, these studies indicate that the fish communities of the Rio Grande have changed both spatially and temporally (Dudley and Platania 1997; Plateau Ecosystems Consulting [PEC] 2001). Issues of concern in recent and ongoing studies are fish distribution, abundance, and habitat associations and requirements. Without knowledge of these basic life-history principles, it is difficult to predict how various management actions would impact certain species.

2.2.2.2 Factors Affecting Riverine Habitat

The Middle Rio Grande is now a highly regulated system subjected to numerous maintenance and management activities overseen by a vast suite of federal, state, municipal, Native American, and private agencies. Discharge in the Rio Grande fluctuates greatly between periods of high spring snow melt runoff and summer drought conditions. High elevation snow-pack, summer rainstorm events, and a few tributaries feed the Rio Grande.

Channel geomorphology has a profound effect on the types and quality of riverine habitats available for aquatic species. Bank modifications and channel stabilization have altered the hydrologic patterns of the system (Reclamation 2000a; USACE 1999). Between 1935 and 1989, there was about a 50% decrease in river channel area in the Middle Rio Grande. The historic Rio Grande floodplain was reduced from widths of over 4,500 ft to less than 3,250 ft and the channel was confined accordingly. This was manifested in a reduction in channel capacity to less than 7,000 cfs for some sections of the Middle Rio Grande while other segments can still sustain 42,000 cfs for short periods (Crawford et al. 1993). Narrowing of the river channel greatly reduces the area of habitat available for all species and their differing life stages.

In-channel fragmentation and intermittency is an important issue in riverine systems. Under most circumstances, a river in its natural state maintains flow from upstream to downstream areas, at least during critical reproductive times. This can be an important issue regarding fish conservation because some fishes rely on river connectivity for survival and reproduction. Major dams, several diversion dams, and the Low Flow Conveyance Channel (LFCC) are physical barriers to natural channel flow in the Rio Grande drainage, especially when their use causes channel dewatering resulting in displacement of fish and drifting insects.

The Project does not contemplate changes to the current physical infrastructure in the Project Area, or consider the impacts of diversions, except in the case of the operation of the San Acacia Diversion Dam and LFCC. The LFCC was built for the purpose of providing diversion of water to Bosque del Apache National Wildlife Refuge and other beneficial irrigation flows to the area, and for providing reliable conveyance of water to Elephant Butte Reservoir to meet requirements of the Rio Grande Compact. Reclamation shares the cost of operation and maintenance at San Acacia Diversion Dam with the Middle Rio Grande Conservancy District (MRGCD) (Reclamation 2000a; USACE 1999). Dewatering and river channel intermittency are frequent occurrences in the San Acacia Reach during low-discharge events, and current and future water operations at the LFCC are subject to mitigation measures specified in a Biological Opinion resulting from the Programmatic Biological Assessment of Bureau of Reclamation's

Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operation, and Related Non-Federal Actions on the Middle Rio Grande, New Mexico (USFWS 2003b).

The degree to which river fragmentation may affect reproduction and survival of RGSM is not yet fully understood. A study conducted by Dudley and Platania (1997) suggested that middle Rio Grande dam and diversion structures do not prohibit downstream transport of eggs and larvae, but do prevent upstream movement of fishes. The inability of fish to reinvade upstream populations could be detrimental to RGSM because they produce semi-buoyant eggs that drift with the current for 24-48 hours prior to hatching (Dudley and Platania 1997).

The Bureau of Reclamation (Reclamation) has been responsible for stabilizing eroding banks along the Middle Rio Grande, and many bank modifications have been completed since 1995. Riprap and jetties have been used for stabilization of eroding banks. Reclamation (PEC 2001) conducted fishery surveys along Santo Domingo, Cochiti, and San Felipe Pueblos to assess effects of bank modification activities implemented along the Middle Rio Grande. This study documents relatively consistent trends in catch-per-unit-effort (CPUE) at jetty and riprap sites. Variation in CPUE over the years was observed at the natural sites from 1995–1999. There was not a consistent trend of higher CPUE at natural vs. jetty or riprap sites. There were, however, a relatively greater (but not significant) number of species observed in backwater habitats compared to all other natural habitat types. The RGSM was collected most frequently in areas of natural, unaltered bank areas (PEC 2001).

Habitat availability is one of the main drivers in the success or decline of a species (Carlson and Muth 1989). Other driving factors include population genetics and predation or competition by native or non-native species. Important habitat elements for survival and reproduction typically include species habitat requirements, habitat availability, environmental conditions toleration, and competition for all life stages including eggs, drifting larvae, juveniles, and adults.

Water quality also affects riverine habitat. Water temperature is a naturally controlling factor for many aquatic species and the north-south orientation of the Rio Grande in the Project Area provides a temperature gradient that separates most cold-water species from warm-water species in Reach 10 below Cochiti Dam. Other water quality parameters—those more directly affected by human activities—have more complex effects on riverine habitat. Water operations may indirectly affect riverine habitat by decreasing flows and thereby changing the concentration of pollutants, creating thermoclines, and increasing oxygen demand. Resulting poor water quality may fragment the river by making areas temporarily unsuitable for fish or invertebrates.

Historical water operations have affected the flow, temperature, and habitat of the Rio Grande. In turn, this may affect larval and juvenile fish more than they affect adults because of reduced developmental tolerances and swimming performance at these early life-history stages. In addition to altered flow regimes and related habitat modification, many researchers have attributed the decline of native fish fauna in Southwestern riverine streams to predation and competition by nonnative fishes. More recently, parasitism has been also shown to contribute to declines in native fish communities (Brouder and Hoffnagle 1997).

2.2.3 *Upper Rio Grande Reservoir Resources*

2.2.3.1 Reservoir Habitat

Reservoir habitat is the wetted area within a constructed, basically closed-environment that includes both the surface and subsurface aquatic zones. Beginning in the early 1910s, a series of dams were built along the Rio Grande and its tributaries for water storage, flood and sediment control, and hydroelectric generation. A total of eight dams have been constructed including Platoro Dam at the headwaters of the Conejos River; Heron, El Vado, and Abiquiu Dams on the Rio Chama; Jemez Canyon Dam on the Jemez

River; and Cochiti, Elephant Butte, and Caballo Dams on the Rio Grande. These dams have altered the ecosystem in many areas of the Rio Grande drainage through the creation of large reservoirs that allow for fisheries composed mainly of non-native species.

Platoro Reservoir

Platoro Reservoir is located near the headwaters of the Conejos River, a tributary of the Rio Grande, in south-central Colorado about 1 mile west of Platoro in Conejos County. Platoro Dam was constructed in 1951 for the purpose of storing floodwaters of the Conejos River for release when normal flow falls below irrigation requirements in the Conejos Water Conservancy District (CWCD) (Reclamation 2000a). The Reservoir is owned by the U.S. Bureau of Recreation (Reclamation) and is operated and maintained by the Conejos Water Conservancy District (CWCD). Because no changes in operations beyond improved communication are proposed for Platoro Reservoir, it is not considered in detail in this study of biological resources.

Heron Reservoir

Heron Reservoir is located on Willow Creek near the confluence with the Rio Chama, a tributary of the Rio Grande. The reservoir is in north-central New Mexico, about 9 miles southwest of Park View in Rio Arriba County. Heron Dam was completed in 1971 as part of the San Juan-Chama (SJC) Project, which is a transmountain diversion that moves water from the San Juan River Basin, across the continental divide, to the Rio Grande Basin. The Reservoir is strictly for storage and delivery of SJC project water used for municipal, domestic, industrial, recreation, irrigation, and fish and wildlife purposes. Heron Reservoir contains a total storage capacity of 401,320 acre-feet at an elevation of 7,186.1 feet, and a surface area of 5,950 acres at the top of active conservation capacity. The elevation at the top of Heron Dam is 7199 feet and the elevation at the streambed below the dam is 6,937 feet. The reservoir is owned and operated by Reclamation, Albuquerque Area Office.

Heron Reservoir supports a cold-water fishery managed by the U.S. Fish and Wildlife Service (USFWS) and the New Mexico Department of Game and Fish (NMDGF).

El Vado Reservoir

El Vado Reservoir is located on the Rio Chama in north-central New Mexico about 160 miles north of Albuquerque in Rio Arriba County. El Vado dam was built in 1934-35 and was rehabilitated by Reclamation in 1954-55. A new outlet works was built by Reclamation in 1965-66 to accommodate the additional water from the SJC Project. The reservoir is used as storage water for irrigation, recreation, incidental flood control, and sedimentation control. In addition, the reservoir contains a Federal Energy Regulatory Commission regulated hydroelectric plant owned and operated by Los Alamos County. The reservoir is owned by the Middle Rio Grande Conservancy District (MRGCD) and operated by Reclamation under agreement with MRGCD.

El Vado Reservoir supports a cold-water fishery with several warm-water species (Ortiz 2001). Because no changes in operations (beyond improved communication) are proposed for El Vado Reservoir, it is not considered in detail in this study of biological resources.

Abiquiu Reservoir

Abiquiu Reservoir is located in north-central New Mexico on the Rio Chama approximately 30 miles west of Española on U.S. highway 84 in Rio Arriba County. The U.S. Army Corp of Engineers (USACE) completed Abiquiu Dam in 1963 for the purposes of flood control, sediment control, and water supply storage (Reclamation 2000a). The storage capacity of Abiquiu Reservoir is 1,369,000 acre-feet, of which 565,000 are allocated to flood control and sediment storage (Ortiz 2001). The reservoir is at an elevation of 6,362 feet and the total surface area is 16,480 acres (Ortiz 2001). The reservoir is owned and operated by the Corps. A hydroelectric power plant exists below Abiquiu Dam that is owned and operated by Los Alamos County.

Abiquiu Reservoir supports a warm-water and cold-water fishery consisting of Kokanee salmon, rainbow trout, brown trout, cutthroat trout, lake trout, walleye (*Stizostedion vitreum*), green sunfish, largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), white crappie, channel catfish, and bluegill (Ortiz 2001).

Cochiti Reservoir

Cochiti Reservoir is located on the Rio Grande on the Pueblo de Cochiti Indian Reservation in Sandoval County, New Mexico. Cochiti Dam was completed in 1975 by the Corps and is the primary flood control structure for snowmelt runoff on the mainstream of the Rio Grande. Its designated purposes are flood and sediment control, fish and wildlife enhancement, and recreation. The storage capacity of the reservoir is approximately 771,720 acre-feet, with a surface area of 11,176 acres and an elevation of 5,479 feet (Ortiz 2001). The dam is owned and operated by the Corps.

Cochiti Reservoir is primarily a warm-water fishery consisting of northern pike (*Esox lucius*), black bullhead (*Ictalurus melas*), channel catfish, white bass (*Morone chrysops*), striped bass (*Morone saxatillis*), smallmouth bass, largemouth bass, green sunfish, white crappie, black crappie (*Poxomis nigromaculatus*), and bluegill (Ortiz 2001). Cold-water fish species include rainbow trout and brown trout.

Jemez Canyon Reservoir

Jemez Canyon Reservoir is located on the Jemez River just upstream from its confluence with the Rio Grande in Sandoval County, New Mexico. The dam was built by the Corps for both flood and sediment control. The storage capacity for the reservoir is 259,423 acre-feet, with a surface area of 5,300 acres, and an elevation of 5,271 feet (USACE 2000). The Reservoir is owned and operated by the Corps. There is no fishing at this reservoir.

Elephant Butte Reservoir

Elephant Butte Reservoir is located on the Rio Grande approximately 4 miles east of Truth or Consequences, Sierra County, New Mexico. Elephant Butte Dam was originally completed in 1916 by Reclamation. It is the largest and most widely used reservoir in New Mexico. The designated uses for the reservoir are flood control, hydroelectric power generation, and irrigation. The storage capacity of the reservoir is approximately 1,708,200 acre-feet, with 36,500 acres of surface area and an elevation of 4,500 feet (Ortiz 2001). The reservoir and the hydroelectric power plant are owned and operated by Reclamation.

Elephant Butte Reservoir is primarily a warm-water fishery with the exception of rainbow trout and brown trout. Warm-water fish species include white bass, largemouth bass, smallmouth bass, catfish, walleye, and rainbow trout.

Caballo Reservoir

Caballo Reservoir is located on the Rio Grande 25 miles downstream from Elephant Butte Reservoir in Sierra County, New Mexico. The designated uses of the reservoir are irrigation and recreation. Because no changes in operations (beyond improved communication) are proposed for El Vado Reservoir, it is not considered in detail in this study of biological resources.

2.2.3.2 Factors Affecting Reservoir Habitat

Temperature, water quality, reservoir pool fluctuations, thermoclines, turnover, the nature of the drainage basin, and the physical lake morphology are all contributing factors potentially affecting reservoir habitats (Wetzel 1975). For the URGWOPS EIS, only operational changes will be analyzed. These operations may affect reservoir habitats by altering the pool elevation rate-of-change, the lake volume turnover, and the amount of littoral habitat available for fishes and food base organisms.

Reservoir habitats important to aquatic organisms include littoral areas that provide cover for critical life stages and food supplies. Fluctuating lake levels as a result of run-off inflow or water releases for irrigation and municipal water demand can significantly affect the amount of littoral habitats available for aquatic life. In addition, riparian and wetland vegetation provide important habitats in reservoirs and are also impacted by fluctuating reservoir elevations. Aquatic food supply, in the form of zooplankton, may be correlated with lake level fluctuations and the amount of shallow littoral habitats. Water quality, including temperature, is another important element of reservoir habitat, and reservoir fluctuations can affect both water quality and temperature. Degraded water quality and altered temperatures can effect spawning and the development of early life stages of fish and aquatic food base organisms. The baseline study of reservoir habitats in the Project Area, therefore, focuses on determining the qualitative relationship between reservoir surface-level fluctuation—both absolute change during the annual cycle and the rate of change over time—with the abundance and diversity of reservoir fishes.

2.3 *Riparian Habitat*

2.3.1 *Methods*

2.3.1.1 Introduction to the Rio Grande Riparian Ecosystem

Riparian ecosystems are those vegetated zones lying within the floodplain of rivers and affected by riverine hydrology: both the surface and subsurface processes. A riparian area is generally defined as a saturated or flooded transition zone between aquatic and terrestrial systems. Riparian ecosystems are among the most productive in the world. They provide many benefits to society including improvement and preservation of water quality, flood attenuation, habitat for wildlife, and opportunities for recreation and aesthetic appreciation. Great Basin and Chihuahuan Desert Scrub lands and desert grasslands adjoin most of the Rio Grande floodplain from Northern New Mexico to the Big Bend area of Texas. Here the surrounding countryside receives less than a foot of rainfall per year. In this intensely arid climate, the river and its moist riparian zone and wetlands provide the only available surface water and dense woody vegetation for large distances.

The history of riparian vegetation communities along the Middle Rio Grande is summarized in Hink and Ohmart (1984) and Dick Peddie (1993). Other significant historical studies and reviews are presented by Watson (1912), Baily (1913), Burkholder (1928), Van Cleave (1935), and Ferguson (1945). The dominant vegetation type is riparian forest, locally known as *bosque* from the Spanish term for woods or forest, and is characteristically dominated by cottonwood gallery forest with variable understory woody shrubs and trees. The riparian forest community of the Rio Grande exhibits a variable structural diversity. Canopy trees can obtain heights of up to 20 meters (60 feet) if undisturbed by flood or fire for long periods. Depending upon disturbance history, these gallery forests have understories that range from very dense to open, grassy understories. Thus, the *bosque* provides the primary water and nutrient source, as well as protection and roosting sites that attract numerous species of birds, small mammals, and amphibians. In general, bosque vegetation develops into mature forests when left undisturbed for decades, but may be present at intermediate stages of succession where floods have scoured vegetation from the floodplain.

Riparian forests in the Project Area are dominated by Rio Grande or Fremont cottonwood (*Populus* ssp). These riparian forests also include diverse mixtures of Goodding's black willow (*Salix gooddingii*) or other large trees as the principal species in the canopy. Cottonwood bosques occur with a variety of understory species but most often with coyote willows (*Salix exigua*), seepwillow (*Baccharis salicifolia*), New Mexico olive (*Forestiera pubescens* var. *pubescens*), Russian olive (*Eleagnus angustifolia*), and salt cedar (*Tamarix* spp.).

The riverbank community also includes the young- and intermediate-aged successional vegetation on banks and bars along the main channel. Since these areas experience regular scouring, the vegetation typically does not mature. These areas are subject to frequent flood scour disturbance and typically have similar-aged stands of young cottonwood, coyote willow, Russian olive, and/or secondary riparian forest. A variety of annual forbs are found in areas most frequently flooded. Marshes and emergent wetlands also occur in seasonally or perennially saturated areas. The increased diversity and productivity provided by wetland communities of the Rio Grande floodplain is particularly apparent in this otherwise highly arid environment. These marshes and wetlands are supported by groundwater and provide excellent habitat value to wildlife.

The current extent and condition of mid-aged and mature stands of cottonwood, willow, and other native species are indicators of the current health of the riparian ecosystem. The frequency of successful establishment (recruitment) and extent (acreage) of young-aged native plants are indicators of the future condition of riparian habitat. The establishment of riparian vegetation occurs immediately following the period of peak flows from late May through June when the "cotton (seed) is flying" (Crawford et al. 1993). The flood flows prepare the seed beds by scouring existing vegetation and depositing sediment; the gradually receding waters distribute the seeds on the seedbeds and irrigate them. The seeds require bare soil substrate and resulting seedlings require full sun. Cottonwood and willow will not become established under dense stands of existing vegetation, but are established in high numbers on sunny bars, islands, high-flow channels, backwaters, and banks. Because of annual flow and climatic variability, conditions favorable for cottonwood and willow seedling recruitment and survival occur only once in several years (Crawford et al. 1993). Higher flows following a year of seedling establishment could scour that seedbed, causing damage or destruction to newly recruited plants.

In the early 20th century, salt cedar escaped cultivation and began establishing along many of the rivers of the southwest. Today, monotypic salt cedar stands comprise a major part of southwestern riparian zones. For germination, salt cedar requires the same bare, moist substrate conditions as native species. However, it can produce seeds for up to five months. These seeds remain viable for 12 weeks, thus giving salt cedars a longer seed-dispersal period. This enables the species to spread and germinate with flows that decline later in the summer, such as after late-summer monsoon flows. Along the upper Rio Grande, salt cedar stands occur throughout the floodplain and are becoming prevalent in certain reaches in the project area. Mature salt cedar stands typically exclude all other woody vegetation over time, but salt cedar may range from the principal component to a minor woody component in mixed forest ecosystems. Saltcedar stands are not considered the preferred habitat for much of the wildlife along the Rio Grande. Similarly, Russian olive has become established in the Project Area. While these non-native species do not provide the same habitat quality as native trees and shrubs, they can provide habitat to some wildlife.

Methods of Characterizing Riparian Vegetation Communities

For purposes of the Upper Rio Grande Water Operations Environmental Impact Statement, the area of potential riparian effects, and therefore the area of detailed study, was determined to include both banks of the 50-year floodplain of the Rio Chama and both banks of the 50-year floodplain of the Rio Grande from Velarde, New Mexico to the upper extent of the reservoir pool of Elephant Butte Reservoir. For most of the project area, the presence of levees or bluffs defines the 50-year floodplain.

Rio Grande floodplain riparian community composition and structure has been most thoroughly classified and studied using the structural classification of Hink and Ohmart [H&O] (1984). Comprehensive description of the vegetation of the Rio Grande floodplain was last completed in 1982 (H&O 1984). Some significant vegetation change had been noted in biological studies since that time (Crawford, et al. 1993Fluder, 2003). This scheme was also used in the Bosque Management Plan (Crawford et al. 1993). Alternative classification schemes have been used by others (Dick Peddie 1993), however, a modified H&O system was selected for use in the current study for continuity and comparability with earlier investigations. Hink and Ohmart recognized six structural classes of riparian wetland vegetation in the

Middle Rio Grande (**Figure L-2.2**), each of which was studied for associated fauna. The current study evaluating trends and impacts to riparian and wetland resources from past and future proposed Upper Rio Grande water operations recognizes, uses, and builds upon this important biological classification foundation.

In order to understand the baseline conditions of the riparian community in the Rio Grande floodplain, the Project undertook a systematic and comprehensive vegetation mapping project in the central Rio Grande. The purpose of the project was to map all vegetation within the levees between Velarde and Elephant Butte Reservoir using a modified H&O vegetation classification system assisted by color infrared aerial photography flown in 2002. The inventory of riparian vegetation took place from 2002-2004, from Velarde, New Mexico to Elephant Butte Reservoir on the Rio Grande, and on the Rio Chama from Abiquiu Reservoir to the confluence with the Rio Grande.

Extensive ground-truthing of the aerial photo interpretation was conducted during the growing season wherever access was allowed. Uniform methods of visual estimation of canopy height and density were developed through multiple collaborative sessions with all field personnel. Uniform data sheets and other standardized data input strategies were employed. All areas that could be accessed in the floodplain were verified in the field and polygon boundaries adjusted according to the ground-truthing. Areas that could not be accessed were subject only to imagery-based delineation. Data regarding vegetation, height, density of cover in the different height classes, species composition and relative density in the different height classes, and other notes on the presence of saturated soils or recent inundation were included.

Spatial data for each polygon of vegetation was input into Arc Info Geographic Information System at the Reclamation Technical Center in Denver.

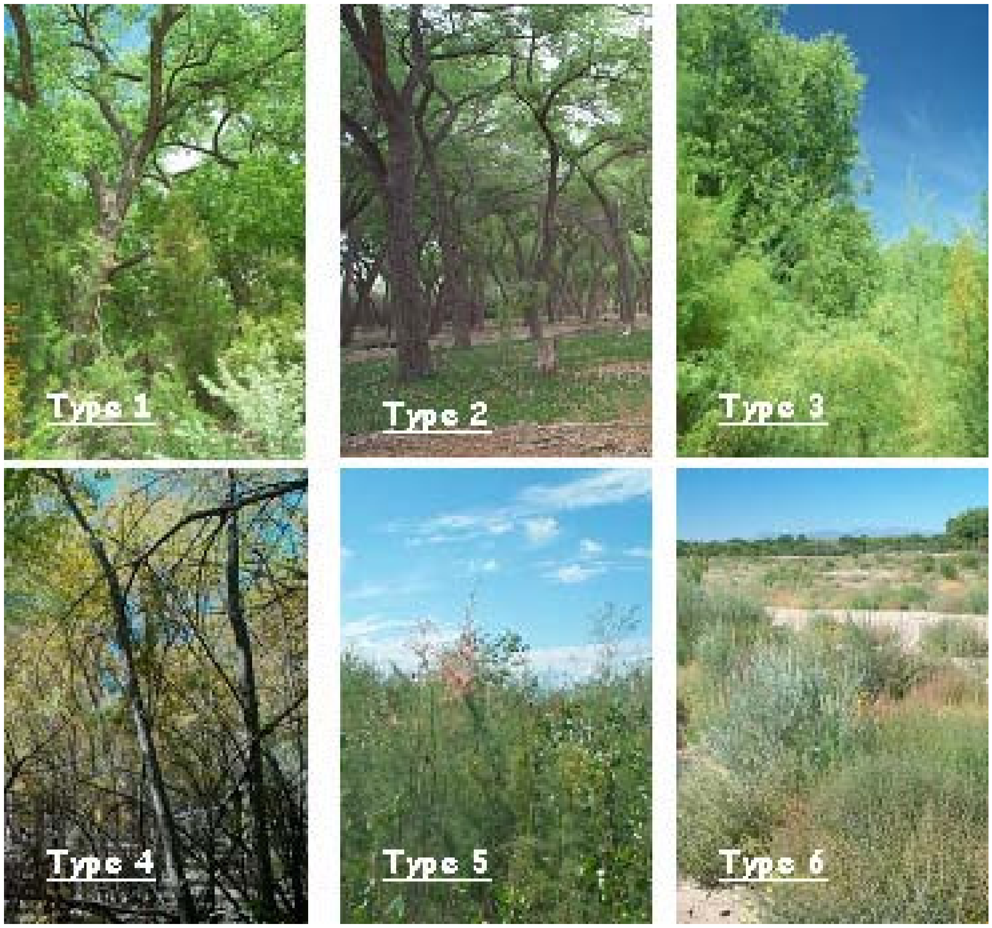


Figure L-2.2 Characteristics of riparian forest vegetation based on Hink and Ohmart 1984 classification system.

Modified Hink and Ohmart Classification

The methods of the inventory consisted of photogrammetric vegetation classification using structural categories based upon and consistent with those utilized by Hink and Ohmart in their 1984 study and then expanded on the species composition to result in a modified vegetation classification. Preliminary areas were established and studied intensively to establish reliable color IR (infrared) signatures for characteristic vegetation types. Imagery was then delineated into polygons of homogeneous vegetation classification types in the lab.

The riparian forest community, particularly the native cottonwood/willow associations, exhibits a variable structural diversity and provides the greatest structural and species diversity of the wetland communities along the Rio Grande. Riparian forest stands, which can obtain heights of up to 20 meters (60 feet), are found with dense to open understories depending on the past disturbance history of the area. In the structural classification of Hink and Ohmart (1984), cottonwood riparian forests occurred in all six structural types identified in their classification (**Table L-2.1**). This classification scheme (**Figure L-2.2**) consists of six structural types based on vegetation height and density, rather than species composition, plus two categories for other habitats.

Table L-2.1 Characteristics of Vegetation Structural Type Classification

Structural Vegetation Type	Height	Other characteristics
Type I	>40 ft (12.2m)	Mature and mid-aged stands with well-developed understory at all heights.
Type II	>40 ft (12.2m)	Mature overstory trees with little or no understory foliage.
Type III	20-40 ft. (6.1-12.2m)	Intermediate-sized trees with dense understory vegetation
Type IV	20-40 ft. (6.1-12.2m)	Intermediate-sized trees with little understory vegetation
Type V	0-15 ft (4.6m)	Younger stands with dense shrubby growth
Type VI	0-5 ft (1.5m)	Very young, low, and/or sparse stands, either herbaceous or woody
Marsh	0-5 ft (1.5 m)	Emergent non-woody vegetation on saturated soil or standing water
Openings/bare	n/a	Less than 25% vegetated

[1](Hink & Ohmart, 1984)

2.3.1.2 Methods to Correlate Vegetation Types with Wildlife Use

The original Hink and Ohmart (1984) survey categorized wildlife presence within the different structural classes. Their data were particularly useful in that they establish the correlation between vegetation types (**Figure L-2.2**) and terrestrial wildlife species richness, composition, and habitat associations. While all structural types have an associated faunal component, the more diverse community types also support a greater diversity of wildlife. This finding has been verified in subsequent studies (e.g. Thompson et al. 1994; Leal et al. 1996). The Riparian Team focused on distinct vegetation communities for which wildlife use was known (**Table L-2.2**).

By establishing which Hink and Ohmart structural classes were most used by wildlife, the Riparian Team had a foundation from which to correlate alternatives impacts to vegetation types with the potential impacts to fauna.

Table L-2.2 Relative Wildlife Value of Community ─ Structure Types (Hink and Ohmart 1984)

Species Descriptions			Structural		Based on Annual Abundance		
Composition	Canopy	Understory	Code*	S-Type	Birds	Mammals	Herps
Native/ Native	C	CW		1	Very Low	Low	Moderate
	C	CW	E	1	Moderate	Moderate	
	C	CW		2	Very Low		
	C	CW	E	3	High	High	Low
	C	CW		4	Very Low	Very Low	High
	C	CW	E	4	Low	Low	
	C	CW		5	Low	Moderate	Low

Species Descriptions			Structural		Based on Annual Abundance		
Composition	**Canopy**	**Understory**	**Code***	**S-Type**	**Birds**	**Mammals**	**Herps**
	C	CW	E	5	High	High	
	C	CW		6	Moderate	Low	Low
	C	CW	A	(6)			Low
Native/ Native	C	J		1	Low	Low	High
	C	J		4	Low	Very Low	High
Native/ Exotic	C	RO		1	Low	Low	Low
	C	RO	E	1	Very High	Moderate	
	C	RO		2	Low	Low	Moderate
	C	RO	E	3	High		
	C	RO		4	Very Low	Low	
Exotic		RO		5	High	Moderate	Low
		RO		6	Low		
Exotic		SC		5	Very Low	Low	
		SC		6	Very Low	Moderate	Low
		SC	E	6	Moderate		
		SC	A	(6)	Very Low	Low	High
Native	MH	(cattail)		5	Very High	High	Low
	MH	(cattail)		6		Moderate	
	MS/MH	(saltgrass)		5	Moderate		

* E = Edge; A = Large, dense, individual plants vs. low, sparse, and relatively uniform

2.3.1.3 U.S. Fish and Wildlife Service Resource Categories

The Project chose to correlate the Hink and Ohmart structural classifications with the Resource Categories defined in the Service's Mitigation Policy (**Table L-2.3**). The Service's Resource Categories also closely link species diversity to specific habitat types. The Service categories focus on ecological suitability of certain habitat types to their associated fauna and related mitigation goals (FR 1981). The Resource Categories of the FWS Mitigation Policy were designed to assist in the development of consistent and effective recommendations for the protection and conservation of fish and wildlife resources. Of particular interest to this EIS are those portions of the Mitigation Policy that address the relative value of habitat types. The habitat types defined by the Policy's Resource Categories each support diverse species but of descending biological value:

Table L-2.3 Correlation of Hink and Ohmart Structural Classes to USFWS Habitat Resource Categories.

Plant Community	Hink and Ohmart (1984) Structural Classes	USFWS Resource Category
Wet Marsh with emergent vegetation	Marsh	1
Cattail Marsh	Marsh	1
Mature Native Canopy / Native Understory	1	2
Mature Native Canopy / Exotic Understory	1	2
Mature Native Canopy / Mixed Understory	1	2
Mature Exotic Canopy / Native Understory	1	2
Mature Exotic Canopy / Exotic Understory	1	3
Mature Exotic Canopy / Mixed Understory	1	2
Mature Mixed Canopy / Native Understory	1	2
Mature Mixed Canopy / Exotic Understory	1	3
Mature Mixed Canopy / Mixed Understory	1	3
Mature Native Canopy	2	2
Mature Exotic Canopy	2	4
Mature Mixed Canopy	2	3
Intermediate Native Canopy / Native	3	2
Intermediate Native Canopy / Exotic	3	2
Intermediate Native Canopy / Mixed	3	2
Intermediate Exotic Canopy / Native	3	2
Intermediate Exotic Canopy / Exotic	3	3
Intermediate Exotic Canopy / Mixed	3	2
Intermediate Mixed Canopy / Native	3	2
Intermediate Mixed Canopy / Exotic	3	3
Intermediate Mixed Canopy / Mixed	3	3
Intermediate Native Canopy	4	2
Intermediate Exotic Canopy 25-75%	4	4
Intermediate Exotic Canopy 75-100% cover	4	3
Native young successional stands	5	2
Exotic young successional stands	5	4
Exotic young successional stands 75-100%	5	3
Mixed young successional stands	5	3
Native sparse young growth	6	2
Exotic young sparce growth	6	4
Mixed young sparce growth	6	3
Opening	OTH	4
Open water	OTH	NA
Saltgrass Meadow	OTH	3

Resource Category 1: Habitat is of high value for evaluation of species and is unique and irreplaceable on a national basis or in the ecoregion section. The mitigation goal for habitat in Resource Category 1 is "no loss of existing habitat value."

Resource Category 2: Habitat is of high quality for evaluation species and is relatively scarce or becoming scarce on a national basis or in the ecoregion section. The mitigation goal for habitat in Resource Category 2 is, "no net loss of in-kind habitat value."

Resource Category 3: Habitat is of high to medium value for evaluation species. The mitigation goal for habitat in Resource Category 3 is, "no net loss of habitat value while minimizing loss of in-kind habitat value."

Resource Category 4: Habitat is of medium to low value for evaluation species. The mitigation goal for habitat in Resource Category 4 is, "minimize loss of habitat value."

These resource categories were used to provide guidance to the Project for valuing the types of riparian habitats identified and mapped in the project area using the modified Hink and Ohmart classification system. For purposes of assigning categories to the habitats found in the project area, Resource Category 1 was determined to consist of marshes. These habitats are very rare and provide the highest biological value to wildlife resources. Resource Category 2 was determined to consist of structurally complex young successional riparian forests dominated by native species in the overstory and understory, as well as some structurally complex riparian forests composed of native overstory with exotic understory. These forest types are becoming scarce in the region and provide biological value for a diverse wildlife assemblege. Resource Category 3 was determined to consist of predominantly mixed native and exotic overstory and understory of any height class, and exotic young successional stands if they were extremely dense. These forests provide important cover and food for riparian wildlife, but without the same diversity and value as forests dominated by native species. Resource Category 4 was determined to consist of sparse, thin forests of purely exotic species in all height classes. This class of vegetation provides the least value to those wildlife species dependant on riparian areas. The correlation between Hink and Ohmart classes and Fish and Wildlife Resource Categories is shown in **Table L-2.3**.

Each of the habitat types defined by the Policy's Resource Categories support an associated community of biological species. The degree of effect to specific habitat types, and the potential mitigation of those effects, corresponds to the value and scarcity of the fish and wildlife habitat at risk.

2.3.1.4 Hydrologic Factors Affecting Riparian Ecosystems

Riparian and wetland ecosystems are both ground- and surface-water dependent. Riparian vegetation distribution is along ecological gradients determined by surface flows and groundwater depth. Vegetation structure and composition are affected by the seasonality, frequency, velocity, and duration of surficial flows as well as by the depth to groundwater. There is hydrological specificity for each of the different stages in individual plant life cycle: seed germination and recruitment, seedling establishment, and plant maturation and maintenance (Koslowski 2002; Rood et al. 2003). The changes in surface water hydrology contemplated by the Project may affect both structure and composition of riparian communities. Current operations at the various facilities–to divert water, store water, or to hold back or release floodwater–develop an overall pattern of hydrology that affects these vegetation communities. It should be noted that grazing and agricultural practices also play a role in the vegetation recruitment and biological diversity of river reaches.

Additionally, hydrology affects overall ecosystem health by promoting beneficial biological and physical processes. Most riparian forests are in various stages of succession because the frequency of disturbance by catastrophic flood events is less than the life span of the dominant tree species, as a general rule. Seasonal overbank flooding of established riparian plant communities is necessary to release nutrients from leaf litter, add new nutrients with alluvium deposition, and generally maintain optimum ecosystem health (Koslowski 2002). Lack of flooding in a regulated river promotes the accumulation of leaf litter and woody debris while decreasing decomposition, nutrient recycling, and plant growth. In several reaches of the Rio Grande, the bosque is never or very infrequently flooded, resulting in heavy buildup of dry leaf litter (Molles et al. 1995). Regulated flood flows may prevent overbank floods necessary to scour away existing vegetation and make new seedbeds for cottonwoods and other native trees. Ellis et al. (1999) demonstrated that flooding significantly improves ecosystem functioning, litter de-composition, and fire resistance. Studies by Andersen and Nelson (2003) on the Yampa River in Colorado have corroborated that decomposition of cottonwood leaf litter increases with the duration of flooding.

Water operations at the various facilities on the Rio Grande produce an overall pattern of hydrology that affects riparian communities in that it moderates surface and groundwater available to the riparian zone. Many areas of the Rio Grande floodplain, both inside and outside the levees, contain relict stands of mature cottonwood and willow that have not flooded for several decades. Current river processes associated with the Rio Grande, such as channel narrowing, aggradation, and degradation—as well as the extensive human activities in the floodplain—affect the availability of water supplied to riparian vegetation. As a result, a significant decline in the extent and establishment of riparian communities has occurred (Crawford et al. 1993). In a recent study of surface cover changes of the Rio Grande Floodplain between 1935 and 1989, Roelle and Hagenbuck (1994) documented a 55% decrease in wetland habitat, with the largest decrease occurring in wet meadow, marsh, and pond habitat.

Large-scale recruitment of native cottonwood and willow vegetation may occur following spring peak flows if overbank flows occurred over sparsely vegetated areas, areas buried with sediment, or recently scoured areas. In addition, successful recruitment requires successive years of slightly reduced overbank flows. That is, new seeds require high flows for irrigation, but not so high as to scour away the new seedbeds. The rate of river-stage drawdown is critical for seedling survival, especially in dry, hot summers. Adequate soil moisture must be maintained by groundwater and summer rain to allow seedling survival following germination. Studies at the Bosque del Apache National Wildlife Refuge documented that gradual reductions in flood flows resulted in a gradual decline in the water table. Seedling survival may still occur with higher rates of groundwater decline; however these seedlings rely on soil moisture in the unsaturated soil profile resulting from monsoonal summer rains (Sprenger et al. 2002). Rood et al. report that cottonwood recruitment occurs in a window between mid-May and mid-June—providing the hydrograph stage-decline remains approximately 2.5 cm per day (Rood et al. 2003). The specific correlation between changes in river flow and the water table, and the confounding factors, needs further study (Naumburg et al. 2005).

Timing of the release of stored water is another hydrologic factor affecting all riparian resources. The ability to make use of available storage options at Abiquiu Reservoir could augment downstream flows for conservation purposes. Operational flexibility in the timing and release of stored waters could offset the negative impacts of 0-flow days or days with less than 100 cfs of flow (e.g. during periods of drought). High levels of upstream storage may exist under low-flow conditions, but positive benefits only occur when operations allow downstream delivery during years with low peak flow volumes or allow augmentation of low natural peak flows.

Historically on the Rio Grande, processes of flow variability, avulsions, and lateral channel migration produced a pattern of cottonwood and willow recruitment in patches and scattered locations over a wide geographic range. Variation in a river's flow regime with both high and low flow events are necessary for diversity and sustainability of riparian and aquatic ecosystems, as discussed by Poff et al (1997). Peak flow variability contributes to temporal and spatial variation of channel movement, flooding, and diversity in vegetation, which ultimately contributes to a diversity of habitat types, thereby supporting a greater biodiversity of organisms.

Periodic flooding ensured widespread patterns of establishment and seed formation and resulted in large stands of relatively young cottonwood and willow occurring near the channel, with the most mature stands occurring on the less flood-prone outer edge of the floodplain (Koslowski 2002).

Currently, there is less opportunity for recruitment as the floodplain has narrowed, the river has become more channelized with less lateral migration, and dense stands of riparian vegetation have armored the riverbank. The introduction and spread of salt cedar, Russian olive, and other exotics during the past 80 years has significantly affected the successional stages of riparian plant communities in the Rio Grande floodplain. These invaders readily colonize the same open sites necessary for cottonwood seed germination and seedling survival. Deprived of regular flood flows and scouring, cottonwood and willow recruitment has been reduced along much of the Rio Grande including the Upper Reach of the project area.

Existing stands of riparian vegetation obtain most of their water from the saturated capillary fringe of soil directly above the floodplain groundwater. The vigor of the riparian plants, especially cottonwood and willow, depends on maintenance of groundwater levels within the range of root growth. Although, groundwater fluctuates on a daily, seasonal, and annual basis with river flows, typical maximum depths to groundwater in Rio Grande cottonwood and Goodding willow communities rarely exceed 16.4 feet (Stromberg and Patten 1991a). The suggested hydrological requirements for the H&O vegetation structural types dominated by native vegetation are summarized in **Table L-2.4**.

Table L-2.4 Suggested Hydrology to Maintain H&O Vegetation Structural Types Dominated by Native Species

H & O Structural Type	Suggested Surface Hydrology	Suggested Groundwater Requirements
Type 1	Surficial inundation of soil approximately every 3-5 years to release nutrients, promote seed formation, and support native species regeneration	6-16 foot depth with mid-May to mid-June surface saturation and slow drawdown of capillary fringe during recruitment
Type 2	Irregular surface inundation necessary every 5-10 years to support native species regeneration, if groundwater levels do not exceed 16.4 feet in depth.	10-16 foot depth
Type 3	Surficial inundation of soil approximately every 3-5 years to release nutrients, promote seed formation, and support native species regeneration	5-10 foot depth with mid-May to mid-June surface saturation and slow drawdown of capillary fringe
Type 4	Irregular surface inundation necessary every 5-10 years to support native species regeneration, if groundwater levels do not exceed root zone.	5-15 foot depth, depending on age and species
Type 5	Regular inundation every 2-3 years	2- 5 foot depth at all times
Type 6	Unspecified	Unspecified
Marsh	Unspecified	Groundwater at surface elevation 75% of year
Openings/bare	Seasonal rainfall or occasional scouring floods	None

Crawford et al. 1993; Graf and Andrew 1993; Stromberg and Patten 1991

Willow-dominated communities require frequent surface saturation and shallow groundwater. These include low stature (Type 5) coyote willow communities, intermediate height (Type 3) communities with coyote willow or Gooding’s willow in the understory, or mature (Type 1) tree willow communities. These communities thrive on lengthy periods of saturation, 5-10 foot depth to groundwater, and low frequency and duration of drying droughts (Crawford et al. 1993; Graf and Andrew 1993; Stromberg and Patten 1991a; Stromberg and Patten 1991b).

Cottonwood-dominated communities require spring overbank flooding every few years for natural seedling establishment and early success (Crawford et al. 1993). Cottonwood forests are, therefore, tolerant of inundation during the growing season. Once established, however, cottonwoods can maintain themselves through maturity in areas with infrequent surface inundation if they have reliable groundwater at 6-16 feet in depth (Crawford et al. 1993; Graf and Andrew 1993; Stromberg and Patten 1991a). Much of the existing mature cottonwood gallery forests in the Central Section, both Types 1 and 2, have not received overbank flooding in decades and are not regenerating as a result (Crawford et al. 1993). Unlike willows, however, they do not survive year-round saturation (Kozlowski 2002).

Salt cedar generally reaches heights of 20–40 feet and does not form an overstory in structural Types 1 or 2, although it may be present in the understory. Riparian forests dominated by salt cedar, therefore, tend to be of Types 3, 4, or 5 depending on age, and may become monotypic with age as shade and accumulating debris and salt prevent other species from establishing in the understory. Dense stands of salt cedar usually occur at sites with deeper water tables than will support native cottonwoods, at 15 to 20, or even 30 feet in depth (Horton 1977). As a result, salt cedar communities are able to tolerate very infrequent overbank flooding and longer periods of drought.

A decrease in annual river flows can reduce the growth of extant riparian vegetation. Studies have shown a linear relationship between the growth of native riparian trees, as measured by annual ring-width and annual flow volume (Stromberg and Patten 1991b). For example, during the period of record from 1950 to 1995, the average annual flow volume recorded at the San Marcial gauge was 493,421 acre feet. However, during the period from 1985 to 1995 the average annual flow was 885,583 acre-feet, which represents an above-average period as well as drainage operation of the LFCC. A significant portion of the young- and mid-aged stands of cottonwood and willow developed during this period. As with other southwestern riparian systems, recruitment of cottonwood and willow plant communities of the Middle Rio Grande depend on peak flows and associated overbank flooding timed to correspond with seed dispersal in late spring.

2.3.1.5 2002-2004 Vegetation Survey Results

Beyond the inherent value vegetation has within the ecosystem, it also provides associated wildlife with habitat crucial for nesting, forage, and protection from prey species. Hink and Ohmart's (1984) study showed that greater vegetation diversity, both in plant species and structural classes, correlates with a greater diversity of wildlife species. In general, mature and mid-aged riparian forests with a dense understory support the highest diversity of wildlife species. The survey results for Vegetation classifications Types 1 thru 6 are shown in **Figure L-2.3**.

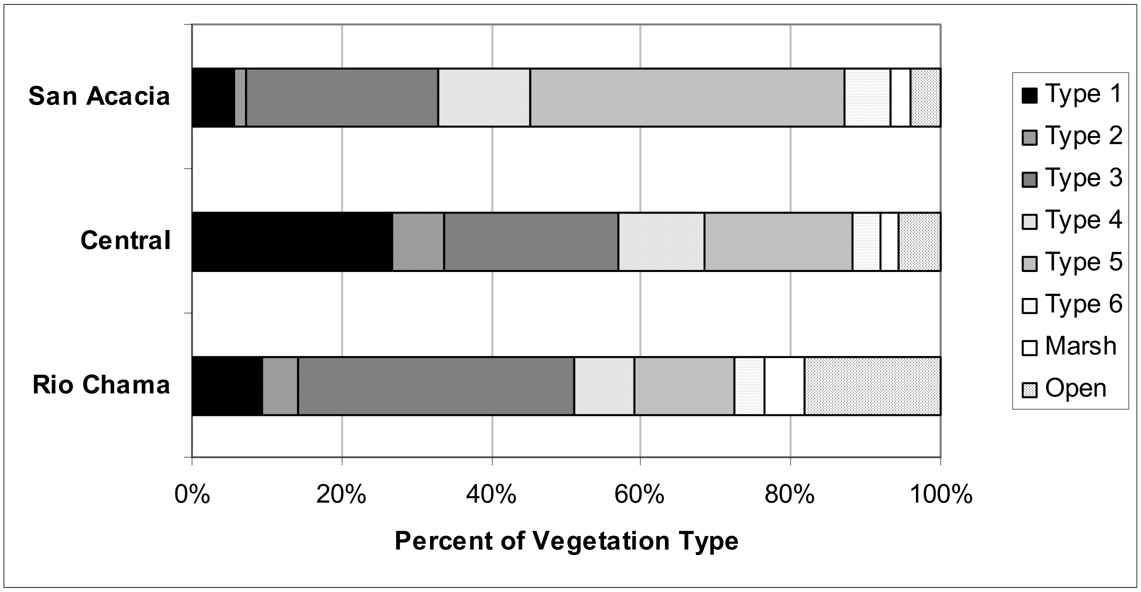


Figure L-2.3 Comparison of Hink and Ohmart structural types by river section.

Northern Section • Rio Grande from Alamosa, Colorado to the confluence with the Rio Chama (Reaches 1, 2, 3, 4)

The Northern Section was not included in the 2002 vegetation surveys because it is outside the area of potential effect of the Project. Description of current vegetation is based on other field surveys and qualitative information (Larry White, US Bureau of Reclamation, personal communication 2004).

Reach 1 – Alamosa, Colorado to the New Mexico State Line

The best extent and condition of riparian vegetation appears at Alamosa NWR and is composed of linear willows stands interspersed with scattered stands of cottonwoods in various age classes and extensive oxbow wetlands. From the south boundary of Alamosa NWR downstream to La Sauses, the floodplain supports scattered stands of willow (*Salix exigua, Salix amygdaloides*), narrowleaf cottonwood (*Populus angustifolia*), and oxbow wetlands.

Reach 2 – Conejos River

From the confluence of the Rio Grande to Platoro Reservoir, the Conejos River supports an extensive area of mixed-age woody vegetation. The upper canopy is narrowleaf cottonwood and various species of montane willows (*Salix* sp.).

Reach 3 – Colorado-New Mexico border to Rio Chama Confluence

In the Rio Grande gorge, riparian vegetation is limited to isolated stands which are restricted by the steep cliffs and deeply incised, narrow floodplain. Upstream of the gorge, the riparian area widens along sweeping meanders in the river and the floodplain opens between rolling cold-desert terrain. The floodplain between the gorge and La Sauses, Colorado has been grazed by livestock for 150 to 200 years and is devoid of woody species and is composed of a well-cropped, weedy grass and forb community. Downstream of the Rio Grande Gorge, the floodplain opens and allows for more extensive stands riparian vegetation on bars and terraces. For several miles downstream of the gorge riparian vegetation is composed of a single canopy layer of salt cedar, coyote willow, and boxelder with a few small isolated stands of cottonwood. Cottonwoods become more common near Embudo and extensive mature cottonwood stands begin near Velarde.

Reach 4 – Velarde to Confluence of Rio Chama

From Velarde downstream to the Rio Chama, the Rio Grande has been channelized and overbank flooding is limited and confined to a narrow active floodplain. A series of several diversion dams limits aggradation and has contributed to a degraded, cobbly riverbed. A mature cottonwood gallery forest with understory of Russian olive, New Mexican olive and one-seed juniper grows on the upper terraces. Isolated narrow bands of coyote willow line the river in or near the limited overbank zone. A few private landowners and the San Juan Pueblo are conducting riparian restoration efforts in the Velarde. This includes Russian olive control and cottonwood/New Mexican olive plantings.

Rio Chama Section • Chama River plus Rio Grande between confluence and Cochiti Dam *(*Reaches 5, 6, 7, 8, and 9)

In New Mexico, the largest tributary to the Rio Grande is the Rio Chama. The 3.2 miles between Heron Reservoir and El Vado Dam encompass Reach 5. Reach 6 is approximately 32-river miles in length and lies between El Vado and Abiquiu dams. Throughout the river channel, which is influenced by water fluctuation, are short-lived weedy plants such as *Xanthium strumarium, Echinochloa crusgalli, melilotus* sp., and *Vebascum thapsus.* Situated between the river channel and the forested floodplain is the scrub-shrub zone characterized by vegetation less than 20 feet high and dominated by willows (*Salix* sp.). In the upper portions of the river, woody species such as *Alnus, Acer, and Baccharis* may be present. Within the river's floodplain, above the scrub-shrub zone, are forested woodlands composed primarily of a mixture of cottonwood (*Populus* sp.) and oak (*Quercus gambelii*). As shown in **Figure L-2-3**, the Rio Chama Section supports the second-lowest percentage of desirable Type I mature riparian forest and the largest percentage of Type 3, in proportion to other river sections.

Reach 5 – Heron Reservoir to El Vado Dam

This stretch exhibits steep canyon walls which drop into the Rio Chama and give way to a thin, linear native vegetation riparian zone that supports willows, some cottonwood, and spruce-fir. Other plants include chokecherry.

Reach 6 – Rio Chama from El Vado Dam to the Monastery

Most of this stretch of the Rio Chama is in a fairly narrow and deep gorge, though the floodplain is somewhat open just below the reservoir as well as at the confluence with the Rio Cebello. For the most part, the area immediately adjacent to the river consists of narrow bands and patches of coyote willow (*Salix exigua*) with one to three terraces above. About 25% of these terraces have riparian vegetation on them, which is typically either old and dying stands of coyote willow or narrow leaf cottonwood (*Populus angustifolia*) groves.

Reach 6 – Rio Chama from the Monastery to Big Eddy Take-out

This section of the Rio Chama is similar to the upstream stretch, though the canyon bottom is typically much wider. The coyote willow is nonetheless still primarily restricted to narrow bands and small patches immediately adjacent to the river. However, there are five or six large patches of mature coyote willow on abandoned meanders. Most of these stands are dying out because they are no longer being regenerated by occasional flooding. The exception is a large, dense stand that is being sustained by periodic flows from an adjacent wash.

Ponderosa pine drops out about a mile above the monastery and Fremont cottonwood (*Populus deltoides*) becomes much more common. There are some fairly sizable cottonwood bosques along the upper part of this stretch. The understories of these wooded areas contain mixes of Rocky Mountain juniper (*Juniperus scopulorum*), New Mexico olive (*Forestiera pubescens*), skunk bush (*Rhus aromatica*), rabbit brush, and other assorted shrubby species.

It is in this stretch that larger numbers of exotics, such as Russian olive (*Elaeagnus angustifolia*) and salt cedar (*Tamarix ramosissima*), are encountered. This is particularly apparent in the lower segment.

Reach 6 – Rio Chama from Big Eddy Take Out to Abiquiu Dam

Big Eddy is located at the farthest upstream pooling area of Abiquiu Reservoir. It is in this region that the Rio Chama leaves the canyon and flows through a more open landscape. As in the upstream segments, very narrow bands and small patches of coyote willow characterize this stretch. The only other dominant woody species in this stretch is salt cedar. Because of fluctuating water levels and well-drained soils, the shoreline of Abiquiu Reservoir contains little vegetation and is quite barren. What vegetation there is tends to be mostly herbaceous and is found in the reservoir delta area and in isolated pockets around the water's edge. There are scattered sparse stands of salt cedar and occasional small Fremont cottonwoods found above the normal high waterline.

Reach 7 – Rio Chama from Abiquiu Dam to Rio Grande Confluence

Only the Rio Chama Section downstream from Abiquiu Dam was mapped, resulting in structural and composition data for 3,073 acres of vegetation. Areas upstream of the pool of Abiquiu Reservoir were unlikely to be affected by proposed actions. Approximately 14% of the mapped riparian vegetation is composed of mature cottonwood forest over 40 feet high, while 45% of the mapped vegetation consists of intermediate stands of mostly native trees with dense shrubby understory vegetation (Hink & Ohmart Types 3 and 4). Young stands of vegetation 5 to 15 feet high accounted for 13% of the vegetative cover, approximately the same percentage as the most mature class, indicating a solid base of replacement forest in this Section. These riparian forest areas are interspersed with about 4% salt grass meadow and 18% openings, and sparsely vegetated with forbs and woody seedlings, as shown in **Table L-2.5**.

Mature cottonwoods dominate the canopy of Reach 7, but many of the acres of Type 1 and 2 vegetation contain an understory dominated by Russian olive. Over 60% of the vegetation (Hink and Ohmart Types 3 and 4) is heavily or moderately infested with non-natives (see Section 2.3.1.8).

The large percentage of intermediate and young vegetation, meadows, and sparsely vegetated openings is especially striking in the Rio Chama section. This vegetation structure indicates a pattern of periodic flood flows of high velocity that regularly disturb the riparian zone and keep it in a desirable state of dynamic succession.

There is considerable agricultural development along the riverside throughout the majority of this segment. Alfalfa fields, pastures, occasional orchards, and residential developments have replaced most of the riparian communities and only small areas of non-cultivated vegetation remain. These sites are typically dominated by Fremont cottonwood, Russian olive, or coyote willow. As in other areas along the Rio Chama, coyote willow is restricted to small patches and narrow bands, and is in many places being displaced by Russian olive. Some of this stretch could not be accessed. Accordingly, some vegetation communities had to be interpreted from aerial photographs.

Table L-2.5 Acres of Mapped Hink and Ohmart Riparian Vegetation in the Rio Chama Section

Hink & Ohmart Structural Type	Acres in Reaches 5, 6	Acres in Reach 7	Acres in Reach 8	Acres in Reach 9	Acreage in Rio Chama Section
Type 1	Not mapped	167	113	5	284
Type 2	“	85	63	0	147
Type 3	“	1,078	46	14	1,138
Type 4	“	222	0	25	247
Type 5	“	262	23	125	410
Type 6	“	89	0	36	125
Marsh/Wet Meadow	“	125	32	3	160
Openings	“	309	228	24	561

Hink & Ohmart Structural Type	Acres in Reaches 5, 6	Acres in Reach 7	Acres in Reach 8	Acres in Reach 9	Acreage in Rio Chama Section
Totals:	**N/A**	**2,337**	**505**	**231**	**3,073**

Reach 8 – Rio Grande from Rio Chama Confluence to Highway 502 Bridge

Vegetation in this reach verified during the 2002-2004 surveys is summarized in **Table L-2.**. Reach 8 included 381 acres of riparian vegetation that were not mapped due to Tribal lands constraints. This stretch includes large sections of private and Pueblo lands with limited or no access. Much of the vegetation analyses for this stretch were based on photographic interpretation.

Reach 9 – Rio Grande Highway 502 Bridge to Cochiti Reservoir

Except for the extreme northern section, most of this stretch of the Rio Grande flows through the steep, cliff-lined White Rock Canyon. Much of the riparian corridor is narrow and contains scattered stands of Russian olive and dense salt cedar. Because of the confining walls, riparian vegetation is often confined to narrow riverside bands, though there are open areas, particularly around the many ephemeral tributaries.

Central Rio Grande Section • Cochiti Dam to San Acacia Diversion Dam (Reaches 10, 11, 12, 13)

Reaches 10 and 11 are primarily tribal lands and vegetation was not mapped. However, the mapped portions reveal that the Central section supports by far the highest percentage of mature Type I riparian canopy with roughly equal portions of Types 3 and 5 vegetation classes (**Figure L-2.3**).

Reach 12 (Bernalillo to Isleta Diversion)

This is the first reach considered a warmwater reach, a condition that prevails in successive downstream reaches. Vegetation mapping was conducted for 1,499 acres in this reach. Although this reach passes through the most heavily settled urban areas of New Mexico, the riparian forests are protected by the Rio Grande Valley State Park. This protection has provided conditions for the riparian areas to become dominated by mature and over-mature cottonwood gallery with dense understory of native and exotic species. The biomass of this reach is typically very high. Vegetation in this reach verified during the 2002-2004 surveys is summarized in (**Table L-2.6**).

Table L-2.6 Acres of Mapped Hink and Ohmart Riparian Vegetation in the Central Section

Hink & Ohmart Structural Type	Acres in Reach 10	Acres in Reach 11	Acres in Reach 12	Acres in Reach 13	Acreage in Central Section
Type 1	0	Not mapped	1,644	1,399	3,043
Type 2	9	“	553	215	777
Type 3	0	“	553	2,122	2,675
Type 4	0	“	189	1,106	1,295
Type 5	0	“	598	1,646	2,244
Type 6	3	“	260	183	446
Marsh/Wet Meadow.	0	“	56	211	267
Openings	0	“	306	327	633
Totals:	12	**N/A**	**4,159**	**7,209**	**11,380**

Reach 13 (extends from Isleta Diversion to the confluence with the Rio Chama).

The Central Section contains the largest vegetative component of mature riparian forest in the study area. Of the 11,380 acres of riparian vegetation mapped in the Central Section, 3,820 acres, or 34% of the total vegetation, is composed of mature cottonwood gallery forest with a high canopy (Types 1 and 2). Riparian forest of intermediate height (Types 3 and 4) accounts for 35% of the vegetative cover. Type 5 vegetation (5 – 15 ft) covers 2,244 acres, or 20%, of the vegetation. Openings, meadows, and marsh accounted for the remaining 12% of cover in this Section.

Regardless of height class, most of the bosque in the Central Section, at least 70%, has a well-developed shrubby understory. Most of the shrubby intermediate vegetation in the understory is composed of non-native species (see Section 2.3.1.8).

Because the trees in the mature cottonwood gallery forest are approximately 60 to 100 years old, the species composition of young stands (Type 5 vegetation) was evaluated to determine if native cottonwood and willows were regenerating. Although this type of vegetation accounts for 20% of the overall vegetation in the section, it was found to contain only about 6% pure stands of coyote willow and young cottonwood. This demonstrates that the cottonwood gallery forest is not being replaced through healthy riparian processes of flood disturbance and seedling establishment and that the current conditions of this section is one of succession to a mixed native and non-native deciduous forest with a low density of cottonwoods. Without regular flood disturbances, fire and human manipulation may have become the factors that regulate the pattern of succession for this section. Vegetation in this reach verified during the 2002-2004 surveys is summarized in **Table L-2.7**.

Table L-2.7 Acres of Mapped Hink and Ohmart Riparian Vegetation in the San Acacia Section

Hink & Ohmart Structural Type	Acres in Reach 14	Acreage in San Acacia Section
Type 1	925	925
Type 2	266	266
Type 3	4,128	4,128
Type 4	2,014	2,014
Type 5	6,774	6,774
Type 6	148	148
Marsh/Wet Meadow.	463	463
Openings	640	640
Totals:	**16,203**	**16,203**

San Acacia Section • San Acacia Diversion Dam to Elephant Butte *(Reach 14)*

The San Acacia Section includes geomorphic Reach 14 that lies between the confluence with Rio Puerco and Elephant Butte Dam. It is influenced by water operations at Cochiti Dam and the Low Flow Conveyance Channel. Riparian vegetation found in this section is listed in **Table L-2.7**. The San Acacia Section contains 16,203 acres of riparian vegetation mapped within the levees, the greatest area of riparian vegetation of the study area. As shown in Figure 2.3, only 8% of the riparian vegetation in the Section is composed of mature cottonwood gallery forest (Types 1 and 2), mostly in the area downstream from San Marcial. Intermediate-height vegetation, 20 to 40 feet high, accounts for 37% of the vegetative cover in this section. These forests are mostly dense with shrubby undergrowth. Type 5 vegetation is the most prolific in this Section, with 42percent of the acreage covered by stands of young vegetation form 5 to 15 feet high. Openings, meadows, and marsh accounted for the remaining 13% of cover in this Section.

The distribution of structural types as shown in Figure 2.3 indicates that the San Acacia Section is in a state of dynamic succession in which the maturation of cottonwood gallery forests is not favored and conditions for dense intermediate forests of mixed native and non-native vegetation are increasing. The San Acacia Section exhibits the highest percentage of non-native infestation (see Section 2.3.1.8).

Riparian habitats occur in the riparian zone of the Rio Grande along the shorelines of Elephant Butte Reservoir as well as at inflow areas of the Rio Grande into the reservoir. Riparian plant communities grow in exposed substrate within the floodpool of Elephant Butte Reservoir. The distribution of riparian habitats in this section varies with physical features and reservoir water levels (Reclamation 2002). The riparian–wetland plant communities occurring at the Rio Grande inflow to Elephant Butte Reservoir collectively covered 6,058 acres in 2002 (Reclamation 2002). They include 3,934 acres of tamarisk shrubland as the predominant plant community, with riparian forest, wet meadow, and marsh occurring to a lesser degree.

The native riparian forest, characterized by mature Rio Grande cottonwood (*Populus fremontii*) and Gooding's willow (*Salix goodingii*) is found primarily at the northern end of Elephant Butte Reservoir and above the reservoir's highest level of inundation along the Rio Grande. Riparian forest accounts for approximately 2,123 acres at the Reservoir. There is only one acre of riparian grassland. When reservoir water levels recede, a mosaic of riparian-wetland plant communities including native riparian forests, wet meadows, and cattail marshes develop into an expanding delta.

From 1985 to 1995, reservoir water levels were maintained near capacity. As a result, substrates suitable for the establishment of riparian-wetland vegetation have been created at many locations where eroded sediments have been re-deposited on beaches. Beaches protected from severe wave action tend to support narrow bands (3-5 feet wide) of riparian habitat comprised primarily of tamarisk shrubland and willow shrubland plant communities, with riparian forest occurring less frequently. Exposed beaches cannot support any riparian-wetland vegetation. At the north end of Elephant Butte Reservoir, sediment deposition by the Rio Grande has created an expansive delta of substrate that is rapidly being colonized by riparian-wetland vegetation. This delta is increasing in size as the reservoir pool is receding, allowing more sediment substrate to become available for plant colonization. Concentric bands of tamarisk shrubland and riparian forest (as well as wet meadow) are commonly found along the shorelines of these bays.

Southern Section • Elephant Butte Dam to Fort Quitman (Reaches 15, 16, 17)

The Southern Section was not included in the 2002 vegetation surveys because it is outside the potential impact area of the Project. Current vegetation description is based on other field surveys (Anne Janik, US Bureau of Reclamation, personal communication 2002).

A narrow tamarisk shrubland community dominates the riparian zone along the reach of the Rio Grande from below Elephant Butte Dam to Caballo Reservoir. Riparian plant communities at Caballo Reservoir total 2,412 acres. Riparian forest accounts for 310 acres, riparian grassland covers 1,162 acres, and the remaining 941 acres are tamarisk shrubland (Reclamation 2002).

The northern end of Caballo Reservoir includes remnants (snags) of the cottonwood bottomland forest of the Rio Grande that have been inundated by the reservoir. Wet meadows or riparian grasslands and cattail marshes occur in shallow areas that are inundated by the reservoirs for most of the growing season. Saltgrass and Bermuda grass are the dominant species within the wet meadow complex with some smaller areas dominated by various mixtures of stinkgrass (*Eragrostis cilianensis*), sedges (*Carex* and *Cyperus* spp.), alkali sacaton (*Sporoboltus airoides*), and sneeze-weed (*Helenium autumnale*). Other plant species of the cattail marshes include bulrushes (*Scirpus* spp.), rushes (*Juncus* spp.), reed canary grass (*Phalarus arundinacea*), common reed (*Phragmites australis*), and giant reed (*Arundo donax*). The north ends of both reservoirs have areas where dead tamarisk, cottonwoods, or willows occur with a sparse understory of marsh or wet meadow plant species.

Riparian plant communities occurring along the shoreline are frequently affected by water level fluctuations, associated erosion, and desiccation of some riparian plant species. Shoreline vegetation along the reservoirs tend to support a narrow band of primarily tamarisk shrubland intermixed with mesquite in some areas. Sub-dominant willow shrubland plant species present include sandbar willow (*Salix interior*), seep willow (*Baccharis glutinosa*), desert willow (*Chilopsis linearis*), Gooding willow and cottonwood. Although not a major component or very diverse, a variety of grasses and forbs occur in these shoreline areas including Bermuda grass, saltgrass, stinkgrass, sedges, prostrate vervain (*Verbena bracteata*) and vine mesquite (*Panicum obtussum*). Concentric bands of wet meadow, tamarisk shrubland, and riparian forest are commonly found along the shorelines of the various bays and in the alluvial fans of several lateral drainages.

Vegetation surrounding the American and Riverside Diversion Dam is characterized as park-like with a few, scattered cottonwoods and native grasses areas that are mowed routinely. The river corridor below American Dam is composed of Distichlis/Cynodon grassland, with the exception of a concrete-lined channelized section just above the Bridge of the Americas downstream for about 3 miles. The vegetative community along the Rio Grande below the Riverside Diversion Dam to Fort Quitman is predominantly a narrow band of tamarisk shrubland (*Tamarix chinensis*).

2.3.1.6 Native versus Non-Native Vegetation

Encroachment of non-native species began in the early 20th Century. This as resulted in riparian vegetation that, while it can provide habitat to some wildlife, it does not provide the same habitat quality as native trees and shrubs. The structural classification of Hink and Ohmart (1984) has provided the most thorough method to determine riparian community composition and structure within the Rio Grande floodplain. Biological studies since the 1982 surveys reveal that some significant vegetation change have occured over the past two decades (Crawford, et al. 1993; Fluder, 2003). The vegetation classification system defined by Hink and Ohmart specifies dominant species compositioin in the overstory and understory, and their structural classes. It does not, however, easily distinguish between degrees of non-native infestation within the riparian community. Additional manipulations were required to categorize communities as to their relative cover in non-native species. The survey protocol used for this EIS enabled a quantitative assessment of actual acres infested by exotic species.

The non-native vegetation found in the canopy of H&O Types 1, 2, 3, and 4 would include species such as Siberian elm, Russian olive, or mulberry. When immature, the same species may form part of the understory of Types 1-4. Lower-stature species, the most predominant of which is salt cedar, are more likely to be found in Type 5 (5 –15 ft) and Type 6 (up to 5 ft) structural classes. Acreage mapped as "Open" has a vegetation cover of less than 25%, and species may be native or exotic. This last fact, in particular, makes it difficult to categorically quantify acres of pure native vegetation. The category of "mostly native" seen in Figure L-2.4 represents mapped areas that appear to be purely native or where the exotic component is less than 25%. All non-native vegetation throughout the Project Area occurs in USFWS Resource Categories 2, 3, and 4; no habitats valued as Resource Category 1 are presently impacted by exotic encroachment.

During the vegetation surveys conducted on behalf of this EIS, 30,656 acres were mapped throughout the three river sections potentially impacted by changes in water management. Incidence of non-native infestation for the entire project area is 67% heavily infested, 6% moderately infested, and areas of pure native or light infestation stand at 18%. The surveys also determined that the three river sections exhibit relatively the same percentages of high (mostly exotic), moderate (mixed exotic/native), and light (mostly native) infestions. This is somewhat revealing when considering that the Rio Chama Section has higher elevations and more montane species, the Central Section has been channelized and controlled within the broader floodplain, a floodplain that flattens by the time it reaches the San Acacia Section, affording overbank flooding and hydrological support not easily achieved by the northern two sections. However, there are important differences between river sections in the relative proportion of non-native communities and species' compostition (see **Figure L-2.4**).

Non-native species are generally viewed as vegetation that should be removed from riparian ecosystems. However, riparian fauna are more associated with structural types than with plant species. Please see Section 2.5.8.3 Faunal Use of Non-native Vegetation for additional baseline information.

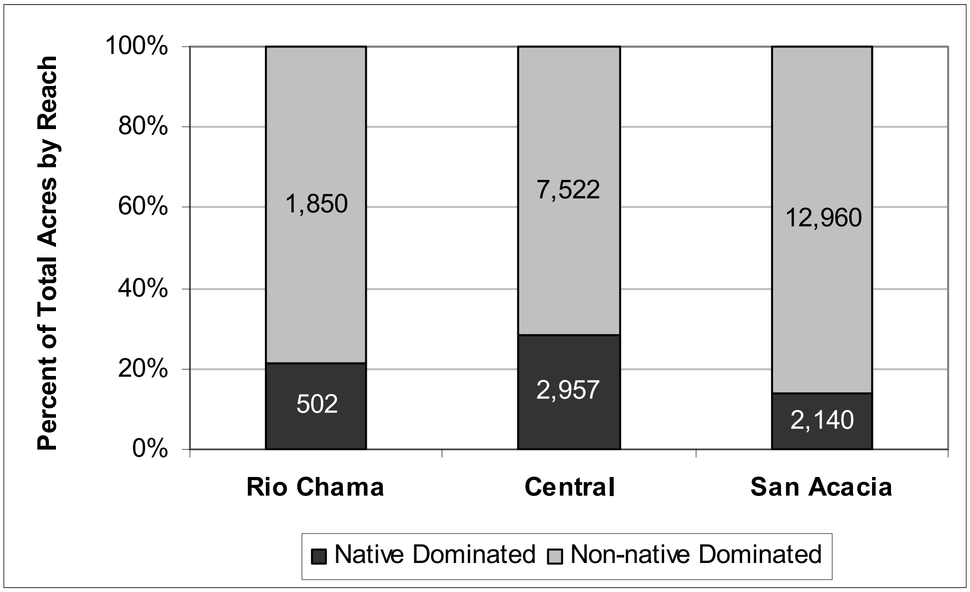


Figure L-2.4 Relative acres of non-native vs. native vegetation in the project area.

Rio Chama Section

This section has the lowest relative acres of heavy to moderate non-native infestation. Of additional interest is the finding that probably 99% of the exotic presence in the Rio Chama is Russian olive. The two Hink and Ohmart types most prevalent in the Rio Chama Section are intermediate Type 3 (1,138 acres) and the 5 – 15 ft. Type 5 vegetation (410 acres). Non-native infestation is heavy in 57% of mapped vegetation and moderate in 3%. This indicates that as much as 60% of native vegetation in these important structural classifications is compromised by exotic species. The third largest acreage type mapped is the openings (561 acres), areas of either bare ground or with less than 25% plant coverage. Sparsely vegetated areas are often more susceptible to exotic encroachment, particularly after periods of disturbance.

The majority of this river section has extensive agricultural development along the riverside. This fact must be considered when assessing any changes in hydrologic management, as a water regime that supports establishment or sustenance of non-natives could contribute to exotic encroachment in agricultural areas as well as in desirable riparian forests.

Central Section

The Central Section has the second-highest acreage of non-native species in the study area, with 66% dominated by moderate to heavy infestations. Like the Rio Chama Section, Russian olive is still the dominant species (in both canopy and understory), but Siberian elm and mulberry begin to appear in Reaches 12 along with salt cedar in the understory. By Reach 13, salt cedar becomes the dominant non-native, not only as an understory species but also in large, monotypic stands of structural Types 5 and 6.

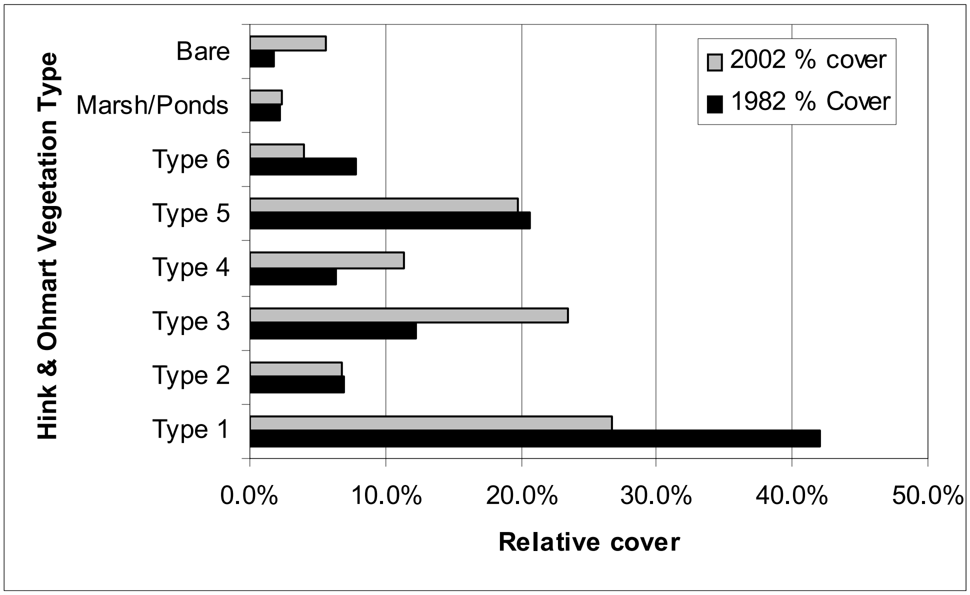
The presence of a dense, mostly non-native understory with very high biomass greatly increases the risk of fire in these forests in dry years. This risk particularly applies to salt cedar. Tamarisk has an oily component that not only makes it extremely flammable, but it burns for an extended time, enabling flames to reach the canopy of mature and intermediate native species. During the period of this study, several fires occurred in the Central Section riparian forest, destroying many acres of riparian vegetation. Exotic infestation could have the highest impacts in the Central Section because it supports the largest mature riparian forest in the study area.

San Acacia Section

Of the three river sections mapped, the San Acacia Section suffers the highest relative percentage of exotic infestation, mostly occurring in intermediate and young height classes. Over 12,000 mapped acres, approximately 74 percent, are dominated by heavy infestation of Russian olive (predominantly in the canopy) and saltcedar. Though the salt cedar is found in the understory, the majority appears as monotypic Types 5 and 6 throughout Reach 14. These same species show moderate infestation in about 800 acres (7 percent). In addition, San Acacia exhibits the lowest acreage (13 percent) of "mostly native" acres, wherein approximately 2,000 acres are purely native or have only light occurrence of non-native vegetation.

2.3.1.7 Vegetation Trends in the Central Rio Grande Section since 1982

The 1982 Hink and Ohmart surveys covered most of the Central Section, as defined in this Project. This survey was conducted after the initial operation at Cochiti Reservoir and provides data gathered during the 2002-03 vegetation survey and mapping, allowing a direct comparison of vegetation composition classes and structural types and how they have changed during the past two decades (FigureL-2.4). Several factors can produce changes in relative cover of different vegetation types within the active floodplain of a river: decline or death of trees from desiccation, germination and rapid growth of young trees, thinning of trees by fire and mechanical clearing, thinning or loss of trees by flood sour. Changes in hydrology and invasion and increase of rapid growing non-native species are presumed to be the primary factors in a highly regulated river system, although some fires and mechanical thinning are known to have occurred during this time period.



FigureL-2.4 Comparison of relative cover of Hink and Ohmart vegetation types, 1982 to 2002 (Chi square=1189, p<0.000).

A chi-square test was applied, which shows that the differences are significant with a chi-square of 1189 with p=0.000 or less. Chi-square Residual tests were applied to further understand the significance and directionality of the observed changes. The data indicate the following trends:

- The riparian zone has seen a significant change in the relative cover of Type 1 vegetation, which has declined since 1982 by 36%. These mature gallery forests with dense understory trees and shrubs provide high levels of biodiversity and valuable support for riparian fauna, particularly avifauna. Loss of this vegetation type can occur from mechanical or fire-induced clearing of the understory. Clearing of the understory of Type 1 vegetation would result transforming it into Type 2 vegetation. The Cottonwood bosque can also be lost completely to fire or mechanical clearing, resulting in Type 6 or Bare classifications. This corresponding trend is not indicated in this study. Death of the mature cottonwood gallery component of Type 1 forests can occur from senescence or drying of the root zone from a lowered water table. This would potentially leave the former understory vegetation unaffected, resulting in a Type 4 or Type 5 forest of intermediate height.
- The relative cover of structural Type 2 vegetation has stayed constant since 1982, declining by only 2%. These forests have a tall cottonwood gallery with a sparse or park-like understory. These forests are usually not the result of natural processes, but result from human-induced clearing of the understory of Type 1 or livestock grazing or both.
- Structural Type 3 has nearly doubled over the twenty-year period, increasing by 92% in relative cover. This vegetation type is likely the result of natural succession of Types 4 or 5, when soil conditions are favorable and frequent inundation occurs.
- An increase of 80% in mid-aged native vegetation (Type 4) was observed. This may be the result of the loss of overstory canopy from Type 1, leaving the understory exposed, or the maturing of Type 5 vegetation in less favorable soils or with less frequent inundation. Both possibilities are supported by the trends observed in this study.
- Type 5 vegetation, the thick shrubby growth of pure stands of young woody species, has decreased by 4% compared to 1982. This may be the result of succession to Type 3 or Type 4

vegetation. This indicates that regeneration of young woody vegetation has decreased slightly.

- A slight increase of 8% in relative cover of non-woody types, such as cattail marshes, ponds, and saltgrass, occurred over the 20-year period.
- The relative amount of structural Type 6 has declined since 1982 by 50% while bare soil increased by 204%. This trend may reflect drought in 2002.

Additional trends were observed in the comparison of native versus non-native composition of the riparian woody vegetation within each structural type. Evaluation of the species composition of each vegetation type indicates the following trend over the past two decades:

- Monotypic stands of non-native vegetation have not increased significantly since 1982, but mixed native and non-native vegetation has increased in most woody vegetation types.
- While Type 2 vegetation has remained constant overall, non-native infestations have increased within this type.
- Significant increases observed in Type 3 vegetation were from large increases in forests with very dense exotic and mixed understory vegetation with some native overstory.
- Significant increases have taken place in native dominated Type 4 vegetation, the only case where native vegetation has increased in actual acreage.
- Native dominated Type 5 vegetation has seen significant decreases while young non-native communities have increased slightly.
- Significant decreases have occurred in Type 6 native dominated vegetation.

2.4 *Wetland Resources*

2.4.1 *Methods*

2.4.1.1 Wetland Characterization Methods

Wetlands have been defined as lands transitional between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by shallow water (Cowardin et al. 1979). Wetland communities are dependent upon frequent surface water inundation or near-surface groundwater. Saturation with water influences soil development and the types of plant and animals living in these habitats. Although wetlands occur within the riparian zone and may be dominated by the same plant species common in riparian woodlands, wetlands exhibit wetter soils and support many additional plant and animal species. Because of their dependence on hydrology, wetlands are highly influenced by changes in water operations.

To evaluate the extent of wetland types within the study area, the Project utilized draft data from a National Wetlands Inventory (NWI) survey performed by the U.S. Fish and Wildlife Service in 2002. This digital coverage included the Rio Grande corridor from Velarde to Elephant Butte Lake and facilitated quantitative analysis of the Rio Grande portion of the Rio Chama Section, the Central Section, and the San Acacia Section. Existing NWI maps were used to grossly characterize the Northern and Southern Sections, and the Rio Chama.

Wetland type terminology adheres to NWI definitions and Cowardin et al. (1979); however, colloquial terms such as *pond*, *marsh*, and *meadow* are utilized for convenience and readability.

2.4.1.2 Overview of Rio Grande Wetland Resources

Historically, the Rio Grande channel wandered widely throughout the floodplain, and abandoned channels often contained sufficient groundwater discharge to support marshes (cienegas), sloughs (esteros), and oxbow lakes (charcos; Scurlock 1998, Ackerly 1999). Widespread and frequent inundation maintained emergent, shrub, and forested wetlands outside of the channel. Currently, the extent of wetland plant communities along the Rio Grande has been significantly reduced (Roelle and Hagenbuck 1994). In addition to direct displacement by agricultural, urban, and water resource development, the groundwater elevation throughout the valley has been lowered by the construction of drains. Irrigation and flood control operations have reduced the magnitude of discharges within the floodway, especially during the spring runoff period, and limit the extent of overbank flooding.

Wetlands occur in a variety of types that may be persistent or ephemeral. Specific wetland types can be characterized by soils, water regime, and vegetation. Along the Rio Grande corridor, soils are the least helpful criterion due to the predominance of recent alluvium with little soil horizon development and the general lack of organic material. Hydrologic factors throughout the system generally dictate the type of wetland that can be supported at a given location. The wetland type, in turn, dictates its primary function within the ecosystem.

Wetlands stabilize streambanks and provide storage areas for floodwaters, protecting downstream areas. Wetlands function as important biological filters to trap sediment and nutrient run-off from surface water and upland environments. In addition, they provide areas of greater biological diversity than the surrounding riparian and upland habitats. They provide breeding sites and wintering areas for numerous wetland-dependent wildlife species, and serve as migratory stop-over areas for waterfowl and shorebirds.

Channels and lakes are wetland types that are largely unvegetated or dominated by submergent plants, and are described in the Aquatic Resources section. The remainder of the current discussion will largely focus on vegetated wetland types.

Pond (Palustrine open water and aquatic bed)

Ponds are shallow-water habitats that may be wet year-round or only intermittently. A natural pond may result in depressions filled by surface water flooding or groundwater discharge. Several large open-water systems have been created adjacent to the Rio Grande floodway to enhance wildlife habitat within the floodplain. Though ponds are relatively rare along the Rio Grande, they provide essential breeding habitat for amphibians and valuable waterfowl habitat along this major migratory corridor. The margins of ponds often support at least a narrow band of wetland vegetation.

Marsh (Palustrine emergent wetland)

Marshes are dominated by herbaceous species and commonly are permanently flooded or maintain surface water during the majority of the growing season. Stands of vegetation are often interspersed by areas of open water. Surface water depth may range from approximately 6 inches in shallow marshes to three feet in deeper marshes. Robust cattails (*Typha* spp.), the principal species of this community, and bulrushes (*Scirpus* spp.) often form dense stands that reach heights between 1 and 3 meters. Shallow marshes may be dominated by shorter grasses, rushes (*Juncus* spp.) and sedges (*Scirpus* and *Carex* spp.). Marshes occur in areas with a very high groundwater table or relatively frequent surface water inundation. They provide the primary habitat for muskrats, waterfowl, rails, egrets, turtles, and frogs. In addition to the relatively natural wetlands described here, very large and productive marshes are maintained through intensive management at refuges and other areas along the Rio Grande.

Wet Meadow (Palustrine emergent wetland)

Wet meadow communities include a variety of shorter (less than 1 meter) herbaceous species with occasional, interspersed shrubs. They generally are flooded for only a short period during the growing season, or are in areas where the water table is very close to the ground surface. Surface water, when present, is usually 30 cm deep or less. Saltgrass meadows occur in areas that may have an elevated salt concentration within the soil, and may not be inundated by surface water for several years.

Important herbaceous species found in this community includes Baltic rush (*Juncus balticus*), common spike-rush (*Eleocharis palustris*), smartweeds (*Polygonum* spp.), common plantain (*Plantago major*), water speedwell (*Veronica anagallis* aquatica), and northern frog fruit (*Phyla lanceolata*). The vegetation in meadows is characterized by a shallow root system. Thus the rate at which the river recedes and the rate of groundwater drawdown are critical for the survival of the vegetation in this community. Wet meadows (along with marshes), provide excellent nursery habitat for fish when inundated and can be important foraging and resting areas for wintering and migratory birds.

Vegetated point bars and islands within the river channel are additional examples of wet meadow wetlands. Due to variations in discharge, vegetation is often highly disturbed or ephemeral. Smartweed, beggartick (*Bidens* spp.), burdock (*Rumex* spp.), and barnyardgrass (*Echinocloa* spp.) are among the first plant species to colonize these areas. Later, a very diverse assemblage of herbaceous plants become established, including bermudagrass (*Cynodon dactylon*), Indiangrass (*Sorghastrum nutans*), reed canarygrass (*Phalaris arundinacea*), alkali sacaton (*Sporobolus airoides*), alkali muhly (*Muhlenbergia asperifolia*), vine mesquite (*Panicum obtusum*), Cuman ragweed (*Ambrosia psilostachya*), and Western goldenrod (*Euthamia occidentalis*) (Milford and Muldavin 2004).

Forested and Shrub Wetlands

Much of the woody riparian plant community along the Rio Grande is sufficiently wet to be also classified as wetland, even though it may not meet classification criterion as jurisdictional wetlands. Close proximity to groundwater or frequent surface inundation are essential in the development of these stands into wetland communities. Shrub wetlands are typically dominated by coyote willow, seep-willow, or salt cedar. Shrub wetland communities are common on point bars and islands, as well as within the overbank area. Forested wetlands in the area are dominated by Rio Grande cottonwood or Goodding's willow, and may have a well developed shrub community in the understory. Typically, the herbaceous layer in these types is dense and diverse compared to drier portions of the bosque. Yerba mansa (*Anemopsis californica*), horsetail (*Equisetum arvense*), and Baltic rush (*Juncus balticus*) commonly occur in forested and shrub wetlands.

The naturally vegetated areas within the floodplain of the Rio Grande are mostly composed of forested, shrub/scrub, emergent, palustrine, and lacustrine wetlands, as defned by the U.S. Fish and Wildlife Service (Cowardin et al. 1979). Some pockets of vegetation within the Project area may have become so disconnected from the active channel, that over time it no longer fits wetland criteria, but nearly all vegetation in the area is dependant on groundwater and surface water for part of the growing season. The baseline vegetation survey using the modified Hink and Ohmart classification system roughly correlates with the Cowardian system of wetland classification in that Hink and Ohmart Types 1, 2, 3, and 4 are forested wetland types, Type 5 is comparable to shrub scrub wetland types, and Type 6 and marshes are generally emergent wetlands. Channels, lakes and ponds are largely un-vegetated wetlands.

2.4.1.3 Hydrologic Factors Affecting Wetlands

Marshes and emergent wetlands require the greatest hydrological support, primarily from groundwater. Most marshes are indirectly dependent on surface flows in the river and nearby unlined drains and channels to keep groundwater levels at or very near the ground surface elevation year round (Cowardin et al. 1979; USACE 1987). The water regime of wetlands depends on proximity to the river channel (a source of surface water) and depth to groundwater. Within the Rio Grande and Rio Chama channels, most of the islands and point bars are periodically inundated by river flows and thus support meadow and shrub wetland communities. Side channels that wind through bars frequently support marsh vegetation. Surface water inundation also influences the development of backwater marshes and shrub wetlands at the deltas of reservoirs such as Cochiti Lake. Individually, wetlands within or bordering the river channel may be short-lived because high flow velocities and sediment deposition may, respectively, scour or bury vegetation.

In addition, many areas with riparian vegetation communities described in Section 2.3.1.2. may also qualify as jurisdictional wetlands as defined in the 1987 Corps of Engineers Wetlands Delineation Manual if they possess more rigorous characteristics of soil saturation, hydrophytic vegetation, and hydrology (USACE 1987). Most wetlands outside of the channel have developed in areas with a high groundwater table. Those in shallow basins or relatively far from the river may be seasonally or temporarily flooded; that is, inundated during the majority, or just a portion, of the growing season, respectively. The natural wetlands along the east bank of the Rio Grande at Bosque del Apache NWR are an example of this water regime.

Abandoned channels or depressions deep enough to intersect the regional groundwater table often support permanently or semi-permanently flooded ponds and marshes (Cowardin et al. 1979; USACE 1987). Within the project area, such geologic features support the largest wetland complexes along the Rio Grande. River flows during the spring runoff period have the effect of elevating the regional water table sufficiently to discharge into these wetlands. Those at Isleta Marsh and Madrone Pond are examples large wetlands primarily influenced by groundwater discharge. During the spring runoff period, surface water also may inundate portions of these wetlands, such as those bordering the channel at San Juan Pueblo. Surface water flow from arroyos may also contribute to the wetland water regime, as in the case at the San Antonio Oxbow.

As a result of the large extent of different wetland types, wither jurisdictional or non-jurisdictional, within the project area, selected wetland complexes are described in **Table L-2.8** with locations shown in **Figure L-2.6**. These representative wetland complexes are singled out for evaluation of the effects of proposed changes in water operations. All wetland vegetation and soils in the Project Area are affected by discharge duration in the river channel. The duration of high flows (greater than the 75th percentile) contributes to groundwater recharge and the stability of groundwater elevations and is an indicator of inundation frequency of wetlands located on islands and in the overbank area. The duration of low flows in the river channel (less than the 25th percentile) reduces the capability of the river flow to maintain minimum groundwater levels in adjacent wetlands.

Table L-2.8 Wetland Type, Acreage and Density Within the Rio Grande Floodway (USFWS 2003)

Wetland Type	Rio Chama Section (Rio Grande portion only)	Central Section	San Acacia Section
Pond	84	105	71
Marsh and meadow	327	2,246	737
Shrub wetland	462	457	2,469
Forested wetland	318	214	485
Total	1,191	3,021	3,762
Wetland density (acre/river-mile)	30.9	28.5	58.2

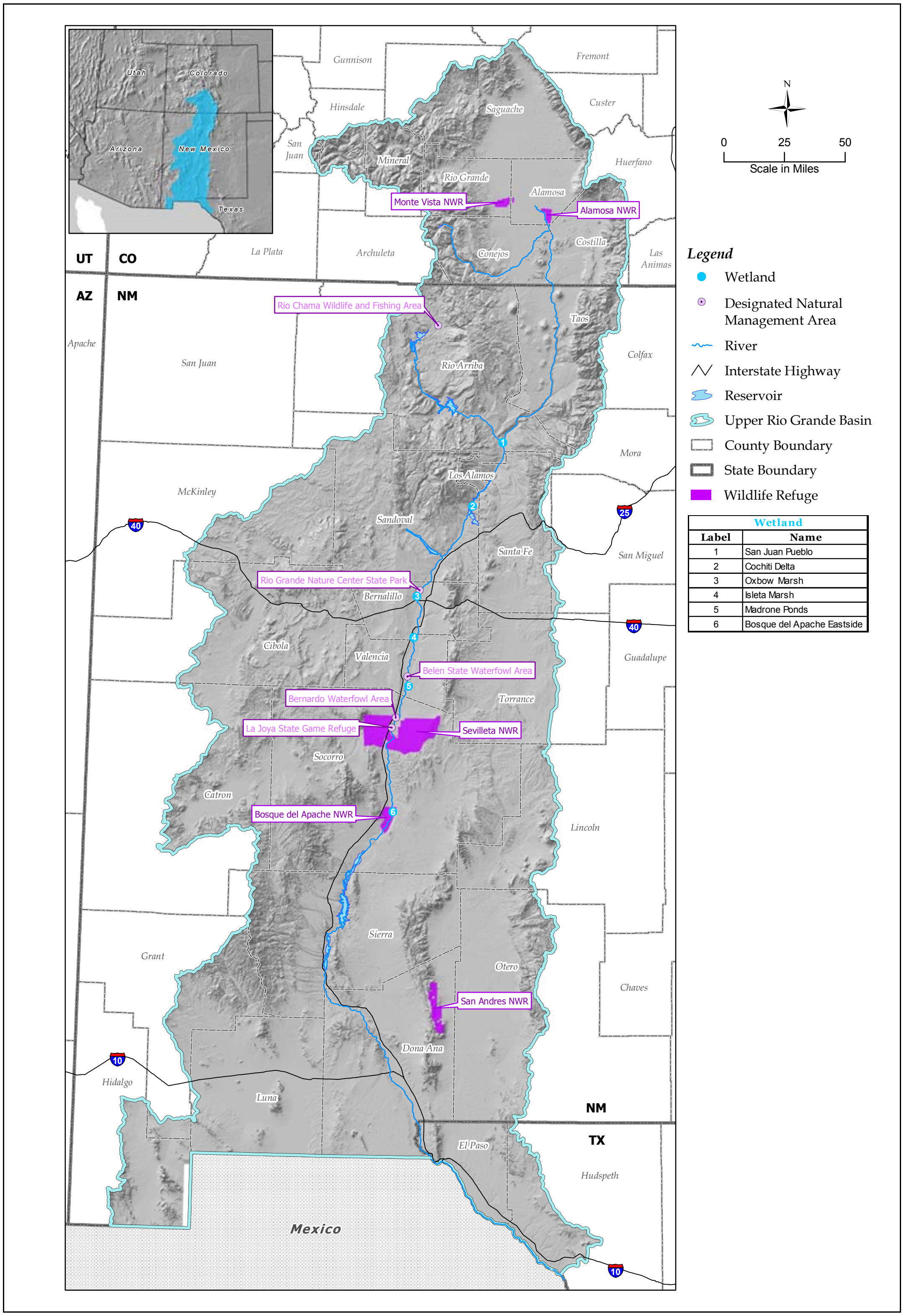


Figure L-2.6 Selected wetlands, refuges, and designated/natural management areas.

2.4.1.4 Distribution of Wetland Types

The areal extent of wetland types within Project river sections was calculated where GIS coverage of NWI data was available and is summarized in **Table L-2.8**. This includes the majority of the river that could be affected by potential changes in water operations. In other reaches, wetland type and extent are qualitatively described. Note that the area of marsh habitat determined from NWI data may not necessarily equate to that determined from the modified Hink and Ohmart classification described earlier because of differences in the classification methodologies.

Northern Section

Upstream of La Sauses, to the south boundary of Alamosa NWR, the floodplain supports oxbow wetlands. The extent and condition of riparian vegetation improves at the Alamosa NWR, which includes extensive oxbow wetlands. There are several small cattail marshes and wet meadows in this reach with the more extensive ones in the Los Luceros area and the south end of San Juan Pueblo. These are usually associated with high groundwater in old river channels and may be supported with irrigation tailwaters and seepage from ditches. These areas provide habitat for a variety of waterfowl, amphibians, and perhaps the New Mexico jumping mouse.

Rio Chama Section

Digital NWI mapping data were available only for the Rio Grande portion of the Rio Chama Section. There is a fairly even abundance of emergent-, shrub-, and forest-dominated wetlands within this section. Nearly 75% of the total wetland acreage occurs between the Rio Chama confluence and Otowi Bridge, including several well-developed marshes. Vegetated wetlands are much less abundant along the narrow channel through White Rock Canyon, and consist primarily of coyote willow stands along the channel margin.

Central Rio Grande Section

The Central Section encompasses more than 3,000 acres of Palustrine wetland, and includes many of the larger wetland complexes such as the San Antonio Oxbow, Isleta Marsh, and Madrone Pond. About two-thirds of the wetland acreage is concentrated between Isleta Diversion Dam and the Rio Puerco confluence (Reach 13). The Central Section has the largest abundance (over 2,200 acres) of marsh and wet meadows, occurring in both relatively large stands at the locales mentioned above, and on many islands and point bars within the Rio Grande channel.

San Acacia Section

Shrub wetland is the most abundant type in the San Acacia Section, accounting for about two-thirds of the 3,762 acres in the section. Over 60% of the nearly 2,500 acres of shrub wetland consists of a mixed coyote willow and salt cedar stands. Marshes are concentrated adjacent to the bluff along the west side of the floodway where groundwater discharges to the river due to the absence of a riverside drain.

Of the three river sections for which acreages could be calculated, the San Acacia section contains nearly 60 acres of wetland per river-mile, nearly twice the density as the Rio Chama and Central Sections. Widespread overbank inundation occurs at relatively low discharges (approximately 3.500 – 4,000 cfs) in section and likely accounts for the abundance of wetland habitat.

Southern Section

Wetland habitats occur in the riparian zone of the Rio Grande, along the shorelines and near-shore shallow areas (littoral zones) of Elephant Butte and Caballo Reservoirs, and at inflow areas of the Rio Grande into the reservoirs. The distribution of these habitats vary with physical features and water levels. Wetland plant communities occurring along the shoreline are frequently affected by water level fluctuations, associated erosion and desiccation of some wetland plants species. The following potential wetland plant communities are represented and include marsh, phreatophyte shrubland (primarily tamarisk), snags in wet meadows, and wet meadow (Reclamation 2002).

At the north end of Elephant Butte Reservoir, sediment deposition by the Rio Grande has created an expansive delta of substrate that is being rapidly colonized by riparian-wetland vegetation. This delta is increasing in size as the reservoir pool is receding allowing more sediment substrate to become available for plant colonization. The size of wetland complexes associated with lateral drainages emptying into Elephant Butte Reservoir appear to be correlated with drainage basin size and isolation of the shoreline from wave erosion. The largest of these wetland complexes is about 2 hectares (5 acres) in size and occur in bays that have several drainage inputs. These bays provide protected coves that are not subjected to severe wave erosion. Subsequently, fine sediments deposited by lateral drainages are retained along the shoreline of these bays and provide substrates suitable for the establishment of wetland habitats. Concentric bands of wet meadow are commonly found along the shorelines of these bays, along with bands of tamarisk shrubland and riparian forest.

The Rio Grande inflow at the northern end of Caballo Reservoir is the largest wetland complex at this reservoir and includes remnants (snags) of the cottonwood bottomland forest of the Rio Grande Valley that was within the inundation limits of the reservoir. The alluvial fans of several large lateral drainages along the western shoreline also support large expanses of wetland. The 16-hectare (40 acre) Palomas Marsh is typical of the wetlands that occur along the western shoreline.

2.4.1.5 Representative Wetlands

Six areas were considered as representative wetlands that fmight be affected by porposed changes in water operations. These were selected on the basis of their geographic location, wetland type and previous study. **Table L-2.9** lists these six representative wetlands within the project area, and their locations are depicted in **Figure L-2.6**. These areas also serve as examples of the various hydrologic conditions that facilitate wetland development within the Rio Grande corridor.

Table L-2.9 Representative Wetland Complexes along the Rio Grande, with Approximate Acreages of Wetland Types

Wetland / Section	Reach	Open water	Emergent wetland	Shrub wetland	Forested wetland	Total
San Juan Pueblo Northern Rio Grande Section	4	1.4	31.8	87.2	0.6	121.0
Cochiti Lake delta Rio Chama Section	9	245.0	23.5	158.7		427.2
San Antonio Oxbow Central Rio Grande Section	12	7.2	36.3	20.2	2.3	66.0
Isleta Marsh Central Rio Grande Section	13	12.3	225.4	125.5	34.8	398.0
Madrone Pond Central Rio Grande Section	13	1.5	35.2	21.6		58.3
Bosque del Apache NWR (east bank) San Acacia Section	14	14.5	141.3	317.0	12.2	485.0

Source: National Wetlands Inventory draft mapping, 2002.

2.4.2 *Designated and Natural Management Areas*

2.4.2.1 National Refuges, State, and Other Wildlife Areas by River Section

There are a variety of Natural Management Areas within the project area, each of which are dependent upon the availability of surface water to maintain specific wildlife habitats that are designated in their Mission. A potential change in water operations could either benefit or adversely affect their ability to manage wildlife habitat.

Northern Section

A number of state and federal wildlife areas provide excellent wetland habitat along the Rio Grande. In the San Luis Valley of Colorado, the USFWS manages 16,000 acres of wetlands, primarily for waterfowl, at the Monte Vista and Alamosa National Wildlife Refuges (NWR). Wetland habitats in the Monte Vista NWR include shallow wet meadows, open water, and cattail marshes as well as grain-producing farmland that provide feed for many waterfowl. Wetland habitats at Alamosa NWR mainly consist of wet meadows, cattail marshes, and river oxbows within the floodplain of the Rio Grande. The Colorado Division of Wildlife and the US Forest Service also actively oversee the management of wetland areas at the Rio Grande and Home Lake Station Wildlife Areas and the Hot Creek Research Natural Area. The wetlands of these wildlife management areas, however, comprise less than 1,000 acres. In addition, they fall outside the project area and thus are given no further consideration.

Recently, BLM has developed The Rio Grande Corridor Coordinated Resource Management Plan to restore degraded sections of the Rio Grande in this Reach. This plan proposes willow and cottonwood plantings and more intensive grazing management, with the goal of bringing degraded habitat back to a healthy, sustainable condition.

Rio Chama Section

The south side of the Rio Chama within reach 5 is part of the Rio Chama Wildlife Management Area, managed by the State. The majority of reach 6 (24.7 miles) was federally designated as “Wild and Scenic” in 1988. The designated area is co-managed by the Bureau of Land Management and the Forest Service.

Central Rio Grande Section

A portion of reach 12 includes Rio Grande Valley State Park, near the Rio Grande Nature Center.

In the Middle Rio Grande, the Belen State Waterfowl Area, Bernardo Waterfowl Area, and the La Joya State Game Refuge, which are managed by the NMDGF, contain wetlands crucial to many species. These wildlife management areas serve as important waterfowl refuges. The Bosque del Apache NWR, a USFWS managed wildlife area located in the Middle Rio Grande 20 miles south of Socorro, covers a total of 57,191 acres, including 13,000 acres of extensive wetlands including wet meadows and cattail marshes. In addition to the state and federal wildlife management areas discussed above, specific wetland areas were identified by Crawford et al. (1993) for the Middle Rio Grande Valley.

Southern Section

The following special areas are located within this reach: Elephant Butte Reservoir State Park; Caballo State Park; Percha State Park; New Mexico Game and Fish Wildlife Management Area at Mesilla Dam; and the Rio Bosque Wetland below Riverside Diversion Dam which is managed by the City of El Paso.

The Natural Management areas discussed above exhibit a variety of management agencies, mission statements, and associated wildlife. () summarizes this diversity by focusing on a few representative management areas.

Table L-2.10 Selected National Wildlife Refuges (NWR) and other Representative Natural Management Areas of the Upper Rio Grande

Name	Location	Size	Description/Mission
Alamosa National Wildlife Refuge	Reach 1	11,169-acres	Natural riverbottom wetland, dissected by sloughs and oxbows of the river; wetland and wildlife habitat
Sevilleta National Wildlife Refuge	Reach 13	229,700 acres	Habitats include bosque riparian forests and wetlands, supports four major ecological habitats; managed to maintain the natural processes of flood, fire, and succession that sustain this diverse ecosystem, vital to migrating birds and other wildlife
Bosque del Apache National Wildlife Refuge	Reach 14	57,191 acres	Waters of the Rio Grande have been diverted to create 7,000 acres of wetlands within total acreage of vital wildlife habitat
Rio Chama Wildlife and Fishing Area	Reach 5	13,000 acres	On the Rio Chama, one of the State's larger and better trout streams (hatchery-stocked rainbow trout)
Rio Grande Nature Center State Park	Reach 10	170 acres	Bosque located within the Central Flyway for migratory birds; wetlands and riparian wildlife habitat
Belen State Waterfowl Area	Reach 11	230 acres	On Rio Grande bottomland; farmed to provide waterfowl feed and resting habitat
Bernardo Waterfowl Area	Reach 12	1,573 acres	Includes 450 acres of crops cultivated to provide winter feed for migratory and upland birds; bird watching and hunting
La Joya State Game Refuge	Reach 12	3,550 acres	Ponds, canals, and ditches in the Central Rio Grande Valley; wildlife and waterfowl protection; bird-watching and seasonal waterfowl hunting

SOURCES: USFWS 2003a; NMDGF 2003b; NM State Parks 2003.

2.4.2.2 Key Rio Grande Restoration Projects

Central Rio Grande Section

The Albuquerque Overbank Project is a joint effort of the U.S. Bureau of Reclamation, the Middle Rio Grande Conservancy District, and the Albuquerque Open Space Division. The purpose of the project is to demonstrate the potential for over banking, that is, clearing river bars of exotic vegetation and regarding to the water table to allow for periodic flooding and re-establishment of native woody vegetation (cottonwoods and willows) in the Middle Rio Grande bosque. Site preparation began in March of 1998. The Middle Rio Grande Bosque Initiative (MRGBI) of the U.S. Fish and Wildlife Service is an ongoing ecosystem management effort to coordinate the ecological restoration and management of the Middle Rio Grande. The U.S. Army Corps of Engineers is also a participant. For this initiative, the Middle Rio Grande is defined as the 180-mile corridor from Cochiti Dam to the headwaters of Elephant Butte Reservoir. The objective of the MRGBI is to protect, enhance, and restore biological values by addressing ecological functions within the Middle Rio Grande based on recommendations by a Biological Interagency Team for long-term protection of the bosque.

Other projects in this section include the Pueblo of Santa Ana Pueblo Riparian and Wetland Restoration projects and Rio Grande Habitat Restoration Project at Los Lunas. The project for the Pueblo of Santa Ana involves rehabilitation and restoration of degraded riverine habitat along the Rio Grande through the Pueblo, stabilizing the severely entrenched riverbed and increasing bankfull channel width. Efforts at Los Lunas included clearing the riverbed and banks of invasive salt cedar and removing jetty jacks to improve flow.

San Acacia Section

Bosque del Apache NWR—The refuge is planning and implementing several projects which require peak flows and overbank flooding to create, enhance, and maintain high quality riparian vegetation and wetlands in the active floodplain (Table L-2.18).

Table L-2.11 Bosque del Apache NWR Restoration Projects

Projects on the Active Floodplain	Acres	Objectives
North End Avulsion – Habitat Improvement	1000	Promote the relocation of the river to the east, stabilize river bar, restore riparian vegetation, create salt grass meadow, and enhance wetland by improving connectivity to river. Monitor river channel/wetland properties
High Flow Side Channel Enhancement – Phase 1	225	Reduce channel narrowing, enhance high flow channels and associated habitat in burned area, monitor channel/floodplain fluvial dynamics
High Flow Side Channel Enhancement – Phase 2	194	Reduce channel narrowing, enhance high flow channels and associated habitat in burned area, monitor channel/floodplain fluvial dynamics
ET Tower Transition Site	443	Control salt cedar in the area of an ongoing evapotranspiration research site to compare water use of salt cedar and restored native vegetation. Also includes channel realignment and the creation of a backwater marsh
Channel Widening and Overbank Area Restoration	750	Widen active channel and re-establish quality riparian habitat along active floodplain
Projects outside the Active Floodplain	Acres	Objectives
Southend Restoration – Phases I and II	1600	Remove monotypic and understory salt cedar, build water delivery system, and manage water to establish wetland, grassland, and forest habitat areas

SOURCE: Gina Dello Russo, Bosque del Apache NWR, personal communication 2004

Floodplain Management Program

The "Save Our Bosque Task Force" is developing a voluntary program for private landowners in the San Acacia reach (in this case, from San Acacia Diversion Dam to the San Marcial Railroad Bridge) to establish conservation easements on those portions of their lands prone to flooding on the active floodplain and work with agencies towards habitat restoration. The Task Force has completed a conceptual plan to determine the mosaic of habitats that could be restored to areas of the floodplain. Approximately 7000 acres of monotypic or mixed salt cedar would be converted to native grasslands, forests, wetlands or savannahs if the plan is fully implemented. One third to one half of the active floodplain in this reach is predicted to flood at or below 5660 cfs (the historic two year return flood). The assumption in the plan is that below 5660 cfs flood level riparian communities with willows, cottonwoods, wetland species could be established and maintained. Above that flood level, salt cedars would be replaced with more xeric species of grasses and shrubs, resulting in open savannahs and scattered trees. (Gina Dello Russo, Bosque del Apache NWR, personal communication 2003).

Southern Section.

Picacho Bosque Wetlands Project

The City of Las Cruces received a U.S. Environmental Protection Agency (EPA) Sustainable Development Challenge Grant to develop a project entitled "Rio Grande Riparian Ecological Corridor Project" in the Mesilla Valley along the Rio Grande. One of the components of the project is the development of a wetland pilot project on land owned by the New Mexico Department of Game and Fish. The 30-acre wetland development project was completed in 2003 with funding from the Elephant Butte

Irrigation District, Bureau of Reclamation, Southwest Environmental Center and City of Las Cruces. The project involved the removal of saltcedar, revegetation with native riparian trees and shrubs, and the creation of wet meadows and open water wetlands.

Rio Bosque Wetlands Park
The University of Texas at El Paso manages this wildlife area for the City of El Paso. The 372-acre wetland park was established in the 1990's and is located along the Rio Grande in southern El Paso County. The wetland park is a result of cooperation of numerous partners including the International Boundary and Water Commission, El Paso County Water Improvement District No. 1, Bureau of Reclamation, Ducks Unlimited and others. Management at the park has included the removal of large stands of saltcedar, planting of native vegetation, and the creation of numerous wetland areas.

2.5 *Fauna of the Rio Grande Valley*

2.5.1 *Riverine Community (fish and foodbase)*

2.5.1.1 Modeling the Riverine Fish Community

Riverine habitat use criteria was developed using five representative aquatic species for the Rio Grande: Rio Grande silvery minnow, flathead chub, longnose dace, river carpsucker, and channel catfish (Bohannan-Huston et al. 2004). For the Rio Chama, brown trout was substituted for the longnose dace. These criteria were developed according to guidelines established similar to the Physical Habitat Simulation Model (PHABSIM) habitat criteria where a statistically based suitability is developed for each specific species and habitat type.

Fish habitat availability on the Rio Chama and Rio Grande was identified and quantified using the results of the hydraulic modeling and habitat suitability analysis and plotting usable habitat area versus discharge. Usable habitat area was calculated for each daily discharge measurement in the 40-year period of record. These data were plotted as a series of flow duration curves for the respective nodes of the URGWOM model for various alternatives (e.g., maximize the percent of usable habitat area for RGSM juveniles following spring runoff). The daily discharge measurements were run through the habitat model to derive daily habitat availability for the 40-year period of record.

Analysis of Rio Grande silvery minnow (RGSM) egg retention, transport, and entrainment were accomplished using the results of the FLO-2D and the URGWOM model. It was assumed that Rio Grande silvery minnow spawn during flow increases in spring (May-June) and that its eggs are uniformly distributed in the water column. The average flow velocity during spawning was quantified by each reach of interest for the 40-year period of record by alternative.

The FLO-2D Model was used to predict average water velocity of the study reaches for a range of discharge events during spring runoff by alternative. The general egg transport rate was estimated using average water velocity data for the reach of interest for a range of flows. The reaches of interest were: Cochiti Dam to Angostura Diversion Dam; Angostura Diversion Dam to Isleta Diversion Dam; Isleta Diversion Dam San Acacia Diversion Dam; and San Acacia Diversion Dam to the headwaters of Elephant Butte Reservoir.

Using the Aquatic Habitat Model, the distribution of habitat (depth and velocity) that could potentially retain eggs/larvae and support their recruitment was predicted. Shallow low velocity habitats were assumed to provide suitable conditions for the growth and survival of young-of-the-year Rio Grande silvery minnow. Changes in these conditions as predicted by the Aquatic Habitat Model were identified by alternative and impact criteria were developed.

A "threshold" velocity was determined that would minimize the downstream displacement of passively drifting Rio Grande silvery minnow eggs and larvae. This value was based on the developmental rate (dependent on water temperature) of Rio Grande silvery minnow and the reach length of interest. The threshold velocity determination (m/s) was expressed as length of fragmented river reach (m) divided by time(s) to development of swim bladder.

The riverine fish community of the Rio Grande within the URGWOPS planning area is comprised of a diversity of native and non-native species. Rio Grande fish community data for the period 1993-2002 are summarized in Section 2.5.2 (**TableL-2.13**).

In a study conducted by the BOR (PEC 2001) 26 fish species, representing nine families, were collected along the Middle Rio Grande study area from 1995 to 1999. The study area extended from Espanola to Socorro, with two sites above Cochiti Dam and six below. Fish diversity was greatest at the San Felipe and Paseo reaches. Common carp (*Cyprinus carpio*) was found in all study reaches, flathead chub (*Platygobio gracilis*) and white sucker (*Catostomus commersoni*) were fairly common and found at 7 of the sites. Longnose dace (*Rhinichthys cataractae*) was observed at 6 sites and did not extend below the Paseo reach (just above Albuquerque). The Rio Grande chub (*Gila Pandora*) was rare within the study reach. The RGSM was only observed at Santa Ana Pueblo, Paseo and Rio Grande Escondida reaches.

Habitat characteristics for six species in five habitat categories were developed for incorporation into the Aquatic Habitat Model described in Section.

2.5.1.2 Estimating the Riverine Food Base

The aquatic food base in the Rio Grande is comprised of various algae, macrophytes, and aquatic invertebrates. Physical features like water velocity, substrate, temperature, and sediment inputs affect these food sources. Impoundments and diversions may also affect the structure of the aquatic food base. The following discussion is based on available data from the United States Geologic Survey (USGS 2003a, unpublished data) and the New Mexico Environment Department (NMED 2003, unpublished data).

Functional Feeding Groups (FFG) are based on the River Continuum Concept (RCC), which consists of three main ideas designed to quantify insect biomass dispersion that can be used as a bio-indicator of the condition of North American streams (Thorp and Covich 1991). The assumptions are based on the concept that stream insect communities originate in response to a continuous gradient of physical variables present from the headwaters to the mouth, and that the aquatic community cannot be separated from the surrounding environmental conditions that introduce water, nutrients and other materials into the ecosystem (Thorp and Covich 1991). It is then also assumed that the entire steam community is linked and what happens downstream is a reaction to what is happening upstream (Thorp and Covich 1991). Theses stream communities are made up of organisms that fulfill different roles and it is those roles that are characterized by FFG classifications.

Establishing a FFG model involves an understanding that longitudinal changes in a stream are associated with the abundance of different FFG and the food resources associated with that group (Thorp and Covich 1991). The determination of a FFG for a certain species is tedious and involves detailed observation of that organism in its natural habitat and analysis of gut contents during different seasons. The actual FFG classes vary among the individuals who use them, but usually involve some basis from the general classes of shredders, collectors, scrapers, macrophyte piercers, predators, parasites, omnivore, and macrophyte herbivores (**Table L-2.19**).

Table L-2.12 Aquatic Food Base Feeding Group Descriptions (Thorp and Covich 1991)

Functional Feeding Group	Abbreviation	Food Source	Feeding Mechanism
Collector Filterers	CF	Decomposing fine particulate organic matter	Filterers or suspension feeders
Collector Gatherers	CG	Decomposing fine particulate organic matter	Gatherers or deposit feeders
Macrophyte Herbivore	MH	Plants	Chewing
Omnivore	OM	Plants or animals	Various
Parasite	PA	Living animal tissue	Internal parasites – eggs, larvae, pupae External parasites – larvae, prepupae and pupae in cocoons, pupal cases or mines
Piercing Herbivore	PH	Plants	Sucking
Predator	PR	Living animal tissue	Engulfers – attack prey and ingest whole animal or parts
Scraper	SC	Periphyton – attached algae and associated material	Herbivores – grazing scrapers of mineral and organic surfaces
Shredder	SH	Living or dead plant material, coarse particulate matter and wood	Chewers of plants and coarse particulate matter, excavate and gallery wood

A concern with these general classifications is that many species will spend time in more than one group during different life stages, seasons, or environmental conditions (Thorp and Covich 1991). There are however general morphological traits that hold some consistency throughout the life history of most organisms, which enable predictions to be made on invertebrate assemblages.

Thorp and Covich (1991) describes the classic premise of the RCC as being that the headwaters of a stream should be narrower resulting in more coverage from the canopy and reduced light exposure thus decreasing photosynthetic production in the water channel. This would in turn reduce the number of scrapers within the assemblage. However, there would be an increase in organic matter input from the surrounding foliage and increase the proportion of shredders with in the insect assemblage. Farther downstream the water channel widens and a greater amount of light hits the water surface and increases photosynthetic production (generally in the form of algae), which results in an increase in scrapers and grazers. Since the vegetation along the shore provides proportionately less organic matter the number of shredders should decrease. Farther downstream, closer to the mouth, the stream again becomes wider and deeper so that much of the substrate is below the photic zone and limits photosynthetic production thus precluding suitable environments for scrapers. Again there is less significant input of organic matter from shoreline vegetation and limits suitable habitat for shredders. There is a larger source of fine particulate organic matter (FPOM) in the water column creating the ideal habitat for collector-filterers and gatherers. Predators and parasite populations tend to remain constant throughout the length of the stream because there is a significant population of prey in most stream habitats.

Data for macroinvertebrates was obtained from sampling sites (USGS 2003a; NMED 2003) along the Rio Grande and major tributaries in Colorado, New Mexico, and Texas. A major tax list was established and functional feeding groups were assigned to each. The data from each sample site was then separated into six general sections of the Rio Grande and the major tributaries. The Northern Section included the Rio Grande from Alamosa, Colorado to the confluence with the Rio Chama. The Chama Section included the Rio Chama from the Heron Dam to the confluence of the Rio Chama and the Rio Grande. The Rio Chama confluence to Cochiti reservoir inflow section included the Rio Grande from the Rio Chama confluence to the Cochiti reservoir inflow. The Central Section included the Rio Grande from Cochiti Dam to the confluence of the Rio Puerco and the Rio Grande. The San Acacia section included the Rio Grande from the Rio Puerco confluence to Elephant Butte reservoir inflow. The Southern Section included the Rio Grande from the Elephant Butte Dam to Fort Quitman. The data from each river section were then sorted by functional feeding groups, and percentages of each group were determined for each section (See Figure in Section 2.5.2). No data were available for the San Acacia section.

2.5.2 *The Riverine Fish Community*

The critical reaches for riverine aquatic habitat under the EIS are from Cochiti Dam to the inflow of Elephant Butte reservoir on the Rio Grande, and the Rio Chama from Abiquiu Dam to the confluence of the Rio Grande. The Rio Grande from the confluence of the Rio Chama to the inflow to Cochiti reservoir may also be important to evaluate under the EIS because of operational changes at Cochiti Reservoir and sport fish management in the reservoir.

Structural modifications to the Rio Grande drainage have eliminated the continuity of the system and created disjointed river reaches. It is therefore important to consider river reaches within the system and their equivalent fish communities (**TableL-2.13**) separately in order to accurately analyze potential impacts to ecologically important areas. These river reaches are designated by continuous river segments that are often from one structural impoundment to the next one downstream, and may combine two or more previously defined reaches into one reach. These reaches are described in the following sections.

Northern Section

A cold-water fishery (brown and rainbow trout) extends from the headwaters of the Rio Grande to Monte Vista (just upstream of Alamosa), below which a gradual transition occurs to a warm-water fishery. The warm-water fishery below Monte Vista supports a variety of non-native fish, including northern pike, largemouth bass, yellow perch, black bullhead, channel catfish, green sunfish, mosquitofish, carp and trench. The native Rio Grande sucker is no longer found in the channel (only in major tributaries), but the river does support native populations of brook stickleback, longnose dace, Rio Grande chub, fathead minnow, red shiner, and white sucker. Lack of flow due to upstream diversions is the primary habitat threat for these species (Montgomery et al. 2001).

Reach 2 – Conejos River

Flowing from the San Juan Wilderness in southern Colorado, the Conejos River is designated from Platoro Dam to the confluence of the Conejos River with the Rio Grande. Fish species include brown, brook, and rainbow trout. The Conejos River is stocked with hatchery fish, managed as a put-and-take fishery, 4.5 miles below Platoro Reservoir after the reservoir flows settle down in late spring.

TableL-2.13 Riverine Fish Distribution in Project Area

Species	Common Name	Section					
		Northern	Rio Chama	Central	San Acacia	LFCC	Southern
Native minnows							
Cyprinella lutrensis	Red shiner		Present	Abundant	Abundant	Present	Present
Gila pandora	Rio Grande chub		Present	Present		Present	
Hybognathus amarus	Rio Grande silvery minnow			Present	Present		

Species	Common Name	Section					
		Northern	Rio Chama	Central	San Acacia	LFCC	Southern
Notemigonus crysoleucas	Golden shiner						Present
Notropis jemezanus	Rio Grande shiner						
Notropis simus	Rio Grande bluntnose shiner						
Pimephales promelas	Fathead minnow		Present	Abundant	Present	Present	Present
Pimephales vigilax	Bullhead minnow						Present
Platygobio gracilis	Flathead chub		Present	Abundant	Present	Present	
Rhinichthys cataractae	Longnose Dace		Present	Abundant	Present	Present	Present
Native species							
Dorosoma cepedianum	Gizzard shad			Present	Present	Present	Present
Dorosoma petenense	Threadfin shad						Present
Gambusia affinis	Mosquitofish		Present	Abundant	Present	Present	Present
Ictalurus furcatus	Blue catfish						
Ictiobus bubalus	Smallmouth buffalo			Present	Present		Present
Lepomis macrochirus	Bluegill			Present	Present	Present	Present
Carpoides carpio	River carpsucker		Present	Present	Present	Present	Present
Catostomus plebeius	Rio Grande sucker		Present				
Pylodictis olivaris	Flathead catfish			Present	Present		Present
Lepisosteus osseus	Longnose gar						Present
Salmo clarki	Cutthroat trout	Present					
Non-native species							
Ameiurus melas	Black bullhead		Present	Present	Present	Present	Present
Ameiurus natalis	Yellow bullhead			Present	Present	Present	Present
Catostomus commersoni	White sucker		Present	Abundant	Present	Present	
Cyprinus carpio	Common carp		Present	Abundant	Present	Present	Present
Ictalurus punctatus	Channel catfish		Present	Present	Present	Present	Present
Lepomis cyanellus	Green sunfish		Present	Present	Present	Present	Present
Lepomis megalotis	Longear sunfish				Present	Present	Present
Micropterus dolomeiui	Smallmouth bass		Present	Present	Present		Present
Micropterus punctulatus	Spotted bass						Present
Micropterus salmoides	Largemouth bass		Present	Present	Present	Present	Present
Morone chrysops	White bass			Present	Present		Present
Morone saxatilis	Striped bass				Present		
Oncorhynchus mykiss	Rainbow trout	Stocked	Stocked	Stocked	Present	Present	Present
Perca flavescens	Yellow perch		Present	Present	Present	Present	Present
Pomoxis annularis	White crappie			Present	Present		Present
Pomoxis nigromaculatus	Black crappie		Present				Present

Species	Common Name	Section					
		Northern	Rio Chama	Central	San Acacia	LFCC	Southern
Salmo trutta	Brown trout	Stocked	Stocked	Present			Present
Salvelinus fontinalis	Brook trout	Present					
Scartomyzon congestum	Grey redhorse						Present
Stizostedion vitreum	Walleye			Present	Present		Present

Reach 3 – from NM-CO state line to Valarde, NM

Brown and rainbow trout are stocked by the New Mexico Department of Game and Fish (NMDGF) at several places on the Rio Grande west of Taos from the John Dunn Bridge south to the Taos Junction Bridge off of State Road 96.

Reach 4 – from Velarde, NM to Rio Chama Confluence

The ichthyofaunal community of this reach was assessed using data collected by Platania (1993a) The Rio Grande at Velarde at the uppermost diversion dam produced a total of eight species that included rainbow trout, brown trout, red shiner, Rio Grande chub, fathead minnow, flathead chub, longnose dace, and white sucker. The most abundant taxon was white sucker followed by fathead minnow, Rio Grande chub, and longnose dace. A second site in Reach 4 (Rio Grande ca. 1.6 km upstream of State Hwy. 74 bridge crossing) produced a similar ichthyofaunal composition with the exception of the loss of rainbow trout and the addition of common carp, black bullhead, western mosquitofish, and largemouth bass. The most commonly collected species included longnose dace followed by white sucker, flathead chub, and fathead minnow.

Rio Chama Section

The fish community of the Rio Chama, the largest tributary of the Rio Grande, may be contrasted from pre and post impoundment periods. Prior to the construction of Abiquiu Dam in 1963, the fish community consisted primarily of native main stem cyprinids including RGSM, Rio Grande bluntnose shiner, Rio Grande chub, and Rio Grande sucker which reached the northern limit of their ranges in the Rio Chama near Abiquiu (Bestgen and Platania 1990). The RGSM is no longer found in the Chama and presently occurs only in the middle Rio Grande between Cochiti Dam and Elephant Butte Reservoir, the Rio Grande bluntnose shiner is now extinct, the Rio Grande chub occurs in low numbers and the Rio Grande sucker is absent. Some native cyprinids, which persisted following dam construction, are generally considered headwater species adapted to cool waters with relatively high velocities. Platania (1996) compared current fish collections to those documented in 1949. Following construction of Abiquiu Dam, the community has shifted towards more headwater type fauna. Introduced brown trout are self-sustaining in the system, and rainbow trout occur but are not self-sustaining. Some fishes stocked into Abiquiu Reservoir occasionally escape into the lower reaches of the Rio Chama. Native fish present in the collections from a Rio Chama habitat availability study (Dudley and Platania 2001) were Rio Grande chub, fathead minnow, flathead chub, and longnose dace. Introduced species included white sucker, rainbow trout, brown trout, western mosquitofish, yellow perch, and channel catfish.

Aquatic habitat in the Rio Chama was subjected to many incidents of low water quality, high sediment load, periods of low to zero flows, and elevated levels of hazardous materials in soil and water samples during the late 1980's and into the 1990's during projects related to the Abiquiu Dam. This poor water quality, while not quantified, is thought to have had detrimental effects on the fish community (Dudley and Platania 2001).

River habitat downstream of Abiquiu dam represents an altered ecosystem, which includes alteration of the natural hydrologic pattern in terms of flow and temperature, and reduction of suspended sediment. These changes have modified the distribution and abundance of aquatic habitats available to native fish.

Reach 5 – Heron Reservoir to El Vado Reservoir

This is a very short river reach that extends between two major flow impoundments (Heron and El Vado reservoirs). Flows are highly regulated because of water releases out of Heron Dam that quickly arrive in El Vado Reservoir. No published information could be found about the ichthyofaunal community that persists in this reach. However, it would seem reasonable to expect that a similar fish community would be found in this reach as is found in Reach 6. Meneks (2002) report on Reach 6 is probably a close description as to the ichthyofaunal community of Reach 5 because of its close proximity to El Vado Dam. Species reported by Meneks (2002) for Reach 6 included: rainbow trout, brown trout, Rio Grande chub, fathead minnow and longnose dace.

Reach 6 – Upper Rio Chama

The Upper Rio Chama reach extends from El Vado Dam to Abiquiu Reservoir. This reach is defined as Reach 6 in the EIS. The reach supports a cold-water game fishery in its upper 15 miles consisting of brown trout, rainbow trout, and Kokanee salmon (BLM 1992). Rainbow trout are stocked by the NMGFD immediately downstream of El Vado Dam, and natural reproduction is not likely since high flows from spring runoff occur during the spawning period (BLM 1992). Brown trout naturally reproduce in the upper 15 miles of the reach and maintaining the brown trout fishery is an important management goal of the NMGFD (BLM 1992). Many trophy-size brown trout are caught within this portion of the river, including the New Mexico state-record brown trout (20 pounds, 4 ounces) (BLM 1992). Channel catfish are another important game fish and are found throughout the entire Wild and Scenic River (BLM 1992). Other non-native fish species that have been recorded in the stream include white sucker, common carp, black crappie, and green sunfish; and native fish species documented include Rio Grande chub, flathead chub, Rio Grande sucker, river carpsucker, longnose dace, and fathead minnow (Hanson 1992). Rio Grande chub are considered a species of concern in New Mexico, Colorado, and Texas.

Meneks (2002) described the abundance of fish species at two sites downstream of El Vado Dam. The first was 1.6 km below the dam and the second was 5 km downstream of the dam. Overall brown trout were the most abundant species comprising 41.95% of fish caught, followed by fathead minnow (19.07 percent) and longnose dace (18.64 percent). At the downstream site brown trout abundance was 55.26 percent; longnose dace abundance was 31.58 percent; and rainbow trout, Rio Grande chub, and fathead minnow each had an abundance of 3.95 percent. At the upper site, brown trout abundance was 35.85 percent, fathead minnow abundance was 26.42 percent, and longnose dace abundance was 12.58 percent. Rainbow trout are stocked by the NMDGF below El Vado Dam on the Chama River.

An in-stream flow assessment was conducted by the Bureau of Land Management (BLM 1992) to determine ideal flow conditions for brown trout and macroinvertebrate habitat. The flow requirements for brown trout are 150-700 cfs from October 15 through March 31, 150-300 cfs from April 1 through August 31, and 75-300 cfs from September 1 through October 15. The flow requirement for macroinvertebrate habitat was determined to be 185 cfs.

Reach 7 – Lower Rio Chama

The Lower Rio Chama reach is designated from Abiquiu Dam to the confluence of the Rio Chama with the Rio Grande. This reach is defined as Reach 7 in the EIS. Several studies have been conducted on the fish community within this reach. Hanson (1992) summarizes the findings of studies conducted from 1988 through 1991. Non-native species documented include brown trout, rainbow trout, white sucker, common carp, and green sunfish. Native species documented include Rio Grande chub, flathead chub, Rio Grande sucker, longnose dace, and fathead minnow. Platania (1991) had similar results with the exception of brown trout were not captured. Platania et al. (1996) documents yellow perch within this reach in addition to the species previously known. (Dudley and Platania 2001) documented river carpsucker, black bullhead, western mosquitofish, smallmouth bass, and a longnose dace x chub hybrid in addition to those species previously documented.

In addition to fish community composition, studies have been conducted on habitat use by species and habitat flow requirements. Platania et al. (1996) found that brown trout occupy a wide range of depths (20-110 cm) but were typically found in water less than 40cm deep, and used a wide range of velocities (0-140 cm/s) but were mostly found in water less than 60 cm/s in velocity. Furthermore, the majority of brown trout (71.5 percent) were present over gravel or cobble substrates with a small percentage (11 percent) occurring over sand and silt substrata. Turner (1982) conducted a study to determine instream flow requirements for fish species in this reach. The findings state that ideal flow for juvenile and fry brown trout is 200 cfs, with at least 65% of the maximum usable area occurring with flows between 50 and 1500 cfs. The ideal flow for adult brown trout is 1500 cfs with at least 75% of the maximum usable area occurring with flows between 100 and 750 cfs.

Rainbow trout and channel catfish were stocked periodically in the lower Rio Chama, prior to 1991, within the first 7.5 miles downstream of Abiquiu Dam. A naturally reproducing brown trout fishery is managed by the NMGFD within this reach.

River Reach 8 – Rio Chama/Rio Grande confluence to Otowi Gage

The ichthyofaunal community of this reach was compiled using data collected by Platania (1993a). The upper sampling site (Rio Grande at State Hwy. 84) of Reach 8 produced a similar catch as upstream sites in Reach 4 with some exceptions. The ichthyofaunal community was composed of gizzard shad, red shiner, Rio Grande chub, fathead minnow, flathead chub, longnose dace, white sucker, Rio Grande sucker, western mosquitofish, green sunfish, and white crappie. The most abundant taxon was flathead chub followed by longnose dace. Other species were much less abundant than these two species. Another sampling site in Reach 8 (Rio Grande, 3 km upstream of State Hwy. 4 (Otowi) bridge crossing) produced similar results. Exceptions included the absence of gizzard shad, Rio Grande sucker, green sunfish, and white crappie. The most commonly collected species included flathead chub, red shiner, and fathead minnow.

River Reach 9 – Otowi Gage to Cochiti Dam

Fish community composition of this reach was assessed using data collected by Platania (1993a). The sampling site (Rio Grande, 3 km upstream of State Hwy. 4 (Otowi) bridge crossing) of Reach 9 produced a somewhat different ichthyofaunal community compared with sites upstream (e.g., Reach 8). Only five fish species were present despite two separate sampling efforts. The most commonly collected species included flathead chub and longnose dace. Other species were rarely collected and included fathead minnow, white sucker, and western mosquitofish. Narrow channel width and increased stream gradient characterize the White Rock Canyon portion of Reach 9. Increased water velocities might explain, in part, the difference in the ichtyofaunal community found in this reach compared to Reach 8.

Central Rio Grande Section

River Reach 10 – Cochiti Dam to to US 550 Bridge

The Cochiti reach extends from Cochiti Dam to the Angostura Diversion Dam and is a portion of Reach 10 as defined in the EIS. At the Cochiti Pueblo in the Rio Grande and Santa Fe River, Platania (1993b) collected seventeen species. Non-native species represented 93.2% of the total catch with white sucker being the most abundant. Five native species were collected with the Rio Grande sucker being the most abundant. Other species collected included the gizzard shad, common carp, red shiner, fathead minnow, longnose dace, river carpsucker, white sucker, rainbow trout, brown trout, mosquitofish, white bass, green sunfish, bluegill, largemouth bass, white crappie, and yellow perch. Lang and Altenbach (1994a) found the same species present.

During September 1995 to October 1999, Plateau Ecosystems Consulting (2001) collected fourteen species in this reach. The white sucker and common carp were the most abundant. The Rio Grande silvery minnow and Rio Grande chub were also present. The Rio Grande chub was found to be restricted upstream of Cochiti Dam and only observed at the uppermost Santa Clara Pueblo reach. Their data suggest that species richness in general may be greater below the Cochiti Dam but varies seasonally.

The NMDGF stocks rainbow trout in the Rio Grande in the outlet works below Cochiti Dam from the parking lots of the Al Black Recreation Area.

Platania (1993b) found seven species at the Angostura Diversion Dam. Red shiner, longnose dace, flathead chub, and the fathead minnow were the most abundant native species collected. Native species represented 86% of the total species collected. Non-native species collected included the white sucker, rainbow trout, and bluegill. The USACE (2000) detected only a few individual Rio Grande silvery minnows in the Rio Grande between Angostura Diversion Dam and Albuquerque during two years of surveys. Approximately 90% of the remaining Rio Grande silvery minnow population is found downstream from the San Acacia Diversion Dam.

River Reach 11 – Jemez Canyon Dam to confluence with Rio Grande

The lower Rio Jemez reach is designated from Jemez Canyon Dam to the confluence of the Jemez River with the Rio Grande. This reach is defined as Reach 11 in the EIS. Species known to occur at the Jemez Canyon Reservoir include the following: largemouth bass, white bass, channel catfish, common carp, sunfish, crappie, white sucker, gizzard shad, and small numbers of brown and rainbow trout (USACE 2000).

A USFWS study (Hoagstrom 2000a) found the most common species in this reach to be common carp, red shiner, fathead minnow, white sucker, and western mosquitofish. These species represented 75.3% of all fish collected with the red shiner and fathead minnow being the most abundant. The study found the Rio Grande silvery minnow to be the tenth most abundant species in the lower Rio Jemez, representing 1.2% of all fish collected. The flathead chub (Federal Species of Concern) has also been found in the Rio Jemez below Jemez Canyon Dam (USACE 2001).

Reach 12 – Bernalillo to Isleta Diversion

The USFWS study (Hoagstrom 2000b) found the Rio Grande silvery minnow present at the Bernalillo Waste Water Treatment Plant Outflow, La Orilla Drain Return, Belen Bridge, Abo Arroyo Confluence, and Isleta Diversion Dam. They found the most common species to be the red shiner, river carpsucker, and western mosquitofish.

Reach 13 – Isleta to Rio Puerco

The Isleta reach is designated from the Isleta Diversion Dam to the San Acacia Diversion Dam. This reach combines Reach 13, running from the Isleta Dam to the confluence of the Rio Puerco as defined in the EIS, and the northern portion of Reach 14 running from the Rio Puerco confluence to the San Acacia Diversion Dam. As defined in the EIS, Reach 14 in its entirety runs from the Rio Puerco to Elephant Butte Reservoir.

The ichthyofaunal community of this reach was assessed using data collected by Dudley et al., 2003. A total of six sampling sites were monitored monthly during 2003 in Reach 13. Large numbers of red shiner, fathead minnow, and western mosquitofish dominated the fish community. These three species were found in high densities during summer months following spawning. Flows in this reach were subject in large variations and large portions of this reach dried completely during summer low flow periods. A large proportion of the flow in the Rio Grande is diverted at Isleta Diversion Dam that defines the upper boundary of this reach. Overall abundance of fish was highest in this reach compared to upstream or downstream reaches. Other fish species present included common carp, Rio Grande silvery minnow, flathead chub, longnose dace, river carpsucker, white sucker, black bullhead, yellow bullhead, channel catfish, white bass, green sunfish, bluegill, largemouth bass, and white crappie.

San Acacia Section

Reach 14 – Rio Puerco to Elephant Butte Reservoir Inflow

For purposes of this fisheries discussion, the San Acacia section is designated from the San Acacia Diversion Dam to Elephant Butte Reservoir, and is the southern portion of Reach 14 as designated in the EIS. It contains two distinct sections – the main stem channel and the Low Flow Conveyance Channel (LFCC). In the main stem channel, the Rio Grande silvery minnow reach their highest abundance in the Rio Grande.

The ichthyofaunal community of this reach was compiled using data collected by Dudley et al., 2003. A total of ten sampling sites were monitored monthly during 2003 in Reach 14. The fish community of the lowest portion of the Middle Rio Grande was composed of many of the same taxa as were found in Reach 13. However, several nonnative taxa were notably absent from Reach 14. Species found in Reach 13 but not Reach 14 included black bullhead, white bass, green sunfish, bluegill, largemouth bass, and white crappie. Large numbers of red shiner dominated the ichthyofaunal community in Reach 14. Flows in this reach were subject in large variations and large portions of this reach dried completely during summer low flow periods. A portion of the flow in the Rio Grande is diverted at San Acacia Diversion Dam. Downstream portions of this reach (between Socorro, NM and San Marcial, NM) were particularly prone to drying during summer months and most of the flow of the Rio Grande was diverted for agricultural uses. Large fish kills have been noted in this intermittent portion of Reach 14 in recent years resulting in greatly depressed fish abundance. Fish species present in this reach included gizzard shad, common carp, Rio Grande silvery minnow, fathead minnow, flathead chub, longnose dace, river carpsucker, white sucker, smallmouth buffalo, yellow bullhead, channel catfish, flathead catfish, western mosquitofish, and yellow perch.

Low Flow Conveyance Channel

In the 1940s the U.S. Army Corps of Engineers developed a comprehensive plan to combat low water flow through the Rio Grande to Elephant Butte Reservoir in attempt to pay an accumulated debt of 500,000 acre feet of water as stated by the Rio Grande Compact of 1938. The plan included the development of the Low Flow Conveyance Channel (LFCC), which was intended to reduce depletion of water in Elephant Butte Reservoir by diverting water from the Rio Grande into a narrower, deeper, more hydraulically efficient channel (Reclamation 2000a). Also, it was used to improve drainage, supplement irrigation water supply and deliver a dependable, year round water supply to Elephant Butte Reservoir and water users downstream (Reclamation 2000a). The LFCC runs parallel to the western side of the Rio Grande from the San Acacia Diversion Dam to the inflow of the Elephant Butte Reservoir and is capable of maintaining a water velocity of 2000 cfs. Currently the average streamflow through the LFCC is between 200 to 300 cfs (Reclamation 2000a). In the past the diversion dam at San Acacia fed the LFCC, but as the streamflow of the Rio Grande increased over the past 20 years the waterline of Elephant Butte Reservoir rose to cover the LFCC outlet thus clogging it with sediment. Water input from the diversion dam has ceased but flow in the LFCC continues as a result of ground seepage from the higher elevated Rio Grande main stem and returns from the canals of the Middle Rio Grande Conservancy District (Reclamation 2000a).

General aquatic habitat within the LFCC is more representative of lentic conditions, with deep, low gradient channels, and stable canal banks. The LFCC is uniformly wide at 66ft. across and has a substrate made primarily of sand. Extensive stands of a parrot feather are found in the channel and along the shores, but are periodically removed. Annual mean stream flows fluctuate greatly from year to year. In 2001 the annual mean stream flow at the San Acacia gauging station was 35.5 cfs while 2000 ran a mean of only 0.37 cfs. The highest recorded mean stream flow at San Acacia was in 1979 and recorded at 1,116 cfs, while the lowest recorded flow occurred in 1993 at only 0.038 cfs (USGS 2003a). In low flow years the LFCC may remain wetted from subsurface inflow and return flow from the Middle Rio Grande Conservancy District. High flow periods such as spring runoff and the summer monsoon season help to transport sediment downstream (Reclamation 2000a). Breaches occur near the downstream end of the

LFCC and form a well-developed channel connecting to the main stem that supports diverse fish communities.

Eighteen fish species were found within the LFCC in an October 1992 inventory. These included the gizzard shad, red shiner, common carp, Rio Grande chub, fathead minnow, flathead chub, longnose dace, river carpsucker, white sucker, black bullhead, yellow bullhead, channel catfish, rainbow trout, mosquito fish, green sunfish, bluegill, largemouth bass, yellow perch, and longeared sunfish. A subsequent survey done by Broderick (2000) from 1997-1998 immediately upstream of the First Breach of the LFCC found nine species in the main channel. Species included black bullhead, bluegill, channel catfish, fathead minnow, largemouth bass, mosquito fish, red shiner, white crappie, and yellow bullhead. Broderick found thirteen species of fish within the First Breach Channel, which included black bullhead, bluegill, common carp, green sunfish, largemouth bass, mosquito fish, red shiner, warmouth, yellow bullhead, Rio Grande silvery minnow, gizzard shad, striped bass, and fathead minnow.

Southern Section

Reach 15-17 – Elephant Butte Dam to Fort Quitman, Texas

The Elephant Butte reach is designated from Elephant Butte Dam to Caballo Reservoir. This reach is defined in the EIS as Reach 15. Six native fish species are known to occur within this reach including gizzard shad, red shiner, river carpsucker, mosquitofish, fathead minnow, and smallmouth buffalo and 22 non-native or uncertain status fish species occur including channel catfish, threadfin shad, rainbow trout, brown trout, longfin dace, goldfish, common carp, bullhead minnow, yellow bullhead, plains killifish, rainwater killifish, sailfin molly, white bass, bluegill, largemouth bass, white crappie, yellow perch, walleye, green sunfish, longear sunfish, smallmouth bass, and black crappie (Propst et al. 1987; Desmare 1978).

The Caballo/El Paso reach is designated from Caballo Dam to El Paso, Texas. This reach is defined in the EIS as Reach 16. Twenty-two species of fish are known to occur within this river reach, eight of which are native to the system (USFWS 2001). These species include longnose gar, gizzard shad, threadfin shad, red shiner, common carp, golden shiner, fathead minnow, bullhead minnow, longnose dace, river carpsucker, smallmouth buffalo, gray redhorse, black bullhead, flathead catfish, channel catfish, green sunfish, longear sunfish, bluegill, largemouth bass, spotted bass, white crappie, yellow perch, white bass, walleye, and western mosquitofish. The NMGFD does not manage this reach for any particular species, however protecting and enhancing the native fish community in the area is an objective of the NMGFD and the USFWS (USFWS 2001a).

Reach 17 – El Paso to Fort Quitman, Texas

The composition of the fish community in this reach was compiled using data from Bestgen and Platania (1988). A total of six sampling sites were monitored to produce this data set. The ichthyofaunal community was composed of twelve species that varied widely in their abundance. The most abundant taxa included gizzard shad and red shiner. Other species were collected in notably lower numbers and included common carp, bullhead minnow, longnose dace, river carpsucker, channel catfish, western mosquitofish, white bass, green sunfish, bluegill, and largemouth bass. Many species were found throughout the sampling reach. However, gizzard shad was absent from the upper portion of the reach but quite abundant in the lower portion of the reach. Other species absent in the upper portion of the reach but present in the lower portion included white bass and largemouth bass.

2.5.3 *The Riverine Food Base*

Data for riverine aquatic foodbase was summarized (**Figure L-2.7**) from unpublished data aquired from NMED and USGS invertebrate surveys (USGS 2003a, unpublished data; NMED 2003, unpublished data). All data used in the following sections were taken from these unpublished data sets.

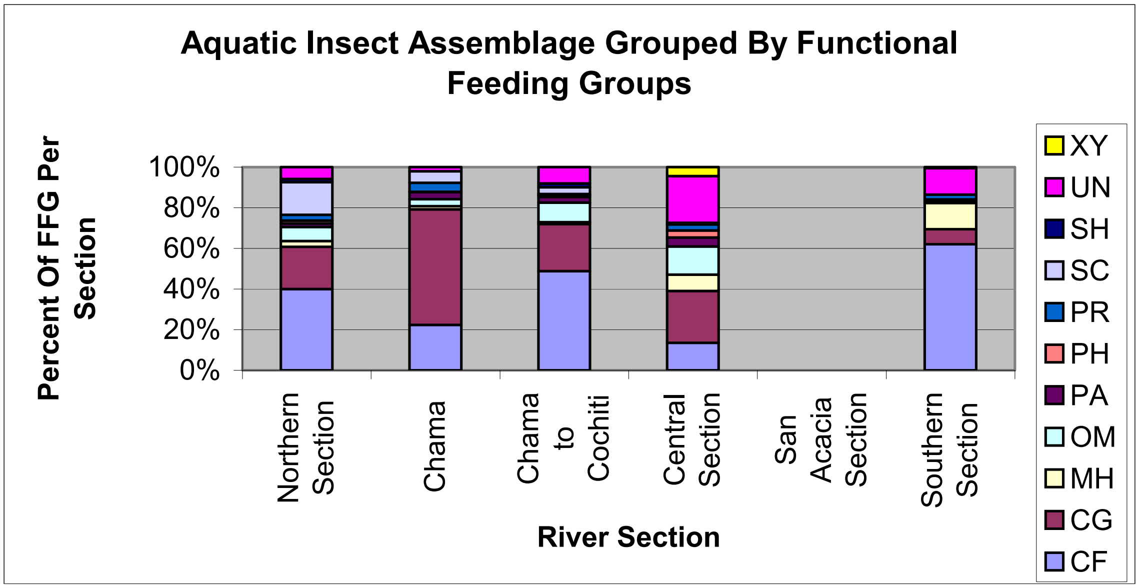


Figure L-2.7 Riverine food base by river section.
(USGS 2003a, unpublished data; NMED 2003, unpublished data).

Figure 2.7 Legend:

XY – Xyliphage	SC – Scraper	OM – Omnivore
UN – Unknown	PR – Predator	MH – Macrophyte Herbivore
SH – Shredder	PH – Piercing Herbivore	CG – Collector Gatherer
	PA – Parasite	CF – Collector Filterers

Northern Section

Flood flows in the Northern Section are unregulated, but water operations of the Closed Basin Project may affect the area. The Northern Section does not include the headwaters of the Rio Grande but rather a series of tributaries merging into the mainstem Rio Grande. None of the sampling sites were near the headwaters of any of the tributaries and so results did not follow in direct accordance with the RCC. The highest percentage FFG in the Northern Section was Collector-Filterers at 39.93 percent, which was followed next by the Collector-Gatherers at 20.93 percent. The abundance Collectors indicates that the sample sites were far enough downstream from the headwater that FPOM makes up a significant food resource. Scrapers made up the third highest percentage at 16.01% and Macrophyte Herbivores accounted for 2.69% of FFG and would indicate much of the organic input is coming from primary production. Shredders made up a very small percentage at only 1.62% and suggest there is not much input of organic matter from shoreline vegetation.

Rio Chama Section

Flows on the Rio Chama are controlled by water operations at Heron, El Vado, and Abiquiu dams. None of the samples were taken near the headwaters of the Rio Chama. The presence of these dams affects the aquatic invertebrate community and corresponding predictions made by the RCC. The largest FFG in the Chama Section was the Collector-Gatherers at 56.81% and was followed next by the Collector-Filterers at 22.42 percent. It is possible that the overwhelming percentage of Collectors is a result of FPOM accumulating and being discharged from reservoirs along the Chama. Scrapers made up the third highest FFG at 5.72% and Macrophyte Herbivores accounted for 1.50%, which indicates there is far less organic input coming from macrophytes and large plants. There was no evidence of the presence of Shredders and would imply there is no input of organic matter from shoreline vegetation or that it is stored, broken down, and discharged as FPOM from the reservoirs along the Rio Chama.

The Chama to Cochiti section is affected by the water operations taking place in both the Northern Section and the Chama Section and also the reservoir inflow of the Cochiti Reservoir, which is regulated by the Cochiti Dam. The Chama to Cochiti Sections largest FFG was Collector-Filterers at 48.78% and Collector-Gatherers were second in frequency 23.11 percent. The third highest were Omnivores at 9.53 percent. Scrapers made up 3.28% and Macrophyte Herbivores made up 1.09% of the FFG, which suggest there is little input of organic material from macrophytes and large plants. Shredders made up 1.80% of the FFG and indicate there is very little organic input from shoreline vegetation.

Central Rio Grande Section

The Central Section water flow is affected by the water operations of all of the sections to the north, but is most directly affected by operations at the Cochiti Dam. The largest FFG in the Central Section was the Collector-Gatherers at 25.54% and the second highest was Unknown FFG at 22.95 percent. The third highest FFG was the Omnivores at 13.89% followed closely by Collector-Filterers at 13.55 percent. It is reasonable to assume that Cochiti Reservoir acts as a storage bank for a variety of food sources including large amounts of FPOM and would account for the large numbers of Collectors and Omnivores. Scrapers made up a very small percentage of the FFG at only 0.77% and Macrophyte Herbivores accounted for 7.94% indicating that conditions are not favorable for algae production but are for aquatic plant production. Shredders were not present in the Central Section indicating there is no significant input of organic matter from shoreline vegetation.

San Acacia Section

No information is currently available for the San Acacia Section.

Southern Section

The Southern Section is most directly affected by operations at Elephant Butte Dam, but is also affected by water operations occurring on all other sections north of the Southern Section. The greatest percentage FFG for the Southern Section was the Collector-Filterers at 62.00% while Collector-Gatherers accounted for 7.40 percent. The second highest FFG was Macrophyte Herbivores at 13.04% indicating that conditions are good for aquatic plant production. The third highest percentage of FFG was the Unknown group at 12.99 percent. Scrapers accounted for 0.06% of the FFG in the Southern Section indicating there is very little production of algae. Shredders were not present in the Southern Section indicating that there is little to no organic input from shoreline vegetation.

The remaining FFG not emphasized in the analysis generally remained constant and insignificant throughout the length of the Rio Grande. Predators were consistent through most of the sections because there is a constant source of food, except in the Chama to Cochiti Section.

2.5.4 *Reservoir Community (fish and foodbase)*

2.5.4.1 Characterizing the Reservoir Fish Community

The reservoir fish community within the planning area was described using existing information obtained from various state and federal sources. These included data from the New Mexico Department of Game and Fish, BISON database (NMDGF 2004a) and staff personal communications (Richard Hansen), as well as the US Fish and Wildlife Service (Ortiz 2001). Fish community data on reservoirs are collected by NMDGF primarily for management purposes and are limited in geographic scope and timing.

2.5.4.2 Estimating the Reservoir Food Base; Zooplankton Sampling Methods

Zooplankton sampling of the five reservoirs of the Rio Grande was conducted over a four-year period following the New Mexico Department of Game and Fish protocol (NMDGF 2003a unpublished data). Samples were not taken consistently from each of the five reservoirs each year.

2.5.5 *The Reservoir Fish Community*

Each reservoir and its fish community are described in the following sections. **Table L-2.14** lists each reservoir and identifies fish species known to occur within these reservoirs. **Table L-2.15** provides life history information for all species known to occur within these reservoirs.

Table L-2.14 Distribution of Fishes in Reservoirs of the Upper and Middle Rio Grande

Fish Species	Platoro	Heron	El Vado	Abiquiu	Cochiti	Jemez Canyon	Elephant Butte	Caballo
Black bullhead					Present		Present	
Black crappie					Present	Present	Present	
Blue catfish							Present	
Bluegill			Present	Present	Present			
Brown trout		Present	Present	Present	Present	Present	Present	
Bullhead minnow							Present	
Channel catfish		Present	Present	Present	Present	Present	Present	
Common carp		Present	Present	Present	Present	Present		
Cutthroat trout		Present	Present	Present				
Fathead minnow		Present	Present	Present	Present		Present	
Flathead catfish							Present	
Flathead chub				Present	Present			
Gizzard shad					Present	Present	Present	
Goldfish		Present	Present	Present	Present		Present	
Green sunfish		Present	Present	Present	Present	Present	Present	
Kokanee salmon		Present	Present	Present				
Lake trout		Present	Present	Present				
Largemouth bass				Present	Present	Present	Present	
Mosquitofish		Present	Present	Present			Present	
Northern pike					Present		Present	
Rainbow trout		Present	Present	Present	Present	Present	Present	
Red shiner		Present	Present	Present	Present		Present	
Rio Grande chub		Present	Present	Present	Present			
Smallmouth				Present	Present			

Fish Species	Platoro	Heron	El Vado	Abiquiu	Cochiti	Jemez Canyon	Elephant Butte	Caballo
bass								
Smallmouth buffalo							Present	
Striped bass					Present		Present	
Threadfin shad					Present		Present	
Walleye				Present	Present		Present	
White bass					Present	Present	Present	
White crappie			Present	Present	Present	Present	Present	
White sucker		Present	Present	Present	Present	Present		
Yellow perch		Present		Present			Present	

Data Sources: Reservoir Fish Species Lists- Ortiz, B. 2001. U.S. Fish and Wildlife Service unpublished report.

Table L-2.15 Life History Information of Fishes in Reservoirs of the Rio Grande

Fish species	Scientific Name	Game Fish	NM Native	Spawning period	Spawning habitat	Spawning depth	Hatch Time	Spawning temp.
Black bullhead	*Ictalurus melas*	Yes	No	spring through summer	shallow water, variety of substrates, under logs or mats of vegetation	shallow	5-10 days	20+ °C
Black crappie	*Poxomis nigromaculatus*	Yes	No	late spring - early summer	mud, sand, or gravel substrates in shallow water with vegetation or overhanging cover	shallow	2-4 days	13-21 °C
Blue catfish	*Ictalurus furcatus*	Yes	Yes	late spring through early summer	pools and backwaters	~2-5m	~6-10 days	21-25 °C
Bluegill	*Lepomis macrochirus*	Yes	Yes	May through mid-August	pools, backwaters with aquatic vegetation cover and mud, silt, or sand substrate	< 1.5m	2-10 days	19.4-26.7 °C
Brown trout	*Salmo trutta*	Yes	No	late fall through early winter	gravel or rubble substrates in riffles, tails of pools, less than 46 cm depth	< 46cm	1-2 months	2-6 °C
Bullhead minnow	*Pimephales vigilax*	No	Yes	spring through summer	shallow water with low currents	shallow	4-5 days	21-26 °C
Channel catfish	*Ictalurus punctatus*	Yes	Yes	spring through summer	shallow water, 2.5-4 m depth under overhead cover or depression	2.5-4m	10 days	20-22 °C
Common carp	*Cyprinus carpio*	No	No	spring through mid-summer	aquatic vegetation, shallow weedy areas	shallow	3-16 days	16.5-28 °C
Cutthroat trout	*Oncorhynchus clarki*	Yes	Yes	March through July	gravel beds in clear silt-free water	semi-shallow	29-48 days	<15 °C
Fathead minnow	*Pimephales promelas*	No	Yes	spring through summer	under rocks at depths of 30-90 cm, 5 cm from bottom in standing water	30-90cm, 5cm from bottom substrate	4-6 days	15.6-18.4 °C

Fish species	Scientific Name	Game Fish	NM Native	Spawning period	Spawning habitat	Spawning depth	Hatch Time	Spawning temp.
Flathead catfish	*Pylodictus olivaris*	Yes	No	summer	under logs, in crevices, and undercut banks	2-5m	6-8 days	22-29 °C
Flathead chub	*Platygobio gracilis*	No	Yes	late summer	seasonal low water habitats with low turbidity and sandy sunbstrate			18-25 °C
Gizzard shad	*Dorosoma cepedianum*	No	Yes	spring	shallow water with sandy or rocky substrate	< 2m	2-4 days	10-22 °C
Goldfish	*Carassius auratus*	No	No	spring until temp. drops below 15 C	aquatic vegetation	shallow	2-10 days	15-23 °C
Green sunfish	*Lepomis cyanellus*	Yes	Yes	spring through late summer	gravel or sandy silt at depths of 4-355 cm	4-355cm	3-5 days	15-31 °C
Kokanee salmon	*Oncorhynchus nerka*	Yes	No	September-January	shallow shorelines, cobel or gravel substrates at depths less than 9.2 m	< 9m	2-5 months	5-12.5 °C
Lake trout	*Salvelinus namaycush*	Yes	No	fall through early-winter	shallow to relatively deep water, rubble or gravel substrate	shallow-deep	4-6 months	7-13 °C
Large-mouth bass	*Micropterus salmoides*	Yes	No	late April through late June	shallow water, gravel substrate preferred, also sand, silt, or mud with boulders, ledges, slopes, or submerged vegetation	1.5-7m	2-5 days	14-18 °C
Mosquito-fish	*Gambusia affinis*	No	No	summer	warm, shallow, standing or slow moving waters, aquatic vegetation or flooded terrestrial plants	shallow	born alive	15-30 °C
Northern pike	*Esox lucius*	Yes	No	spring	flooded vegetation in shallow water, marshy inlets, and mouths of small tributaries	< 0.5m	5-26 days	6-18.5 °C
Rainbow trout	*Oncorhynchus mykiss*	Yes	No	spring	gravel riffles at depths of 15 cm	15cm	9-102 days	6-15.5 °C
Red shiner	*Cyprinella lutrenis*	No	Yes	April through September	clean gravel of riffles, submerged roots, aquatic plants, and rocky shorelines in crevices	shallow	~105 hours	15.5-29.5 °C
Rio Grande chub	*Gila pandora*	No	Yes	March through June	require riffles, no parental care	semi-shallow	5-7 days	14-20 °C
Small-mouth bass	*Micropterus dolomieui*	Yes	No	mid-May through August	sand, gravel, or rubble near protection of rocks, logs, or dense vegetation	< 4m	2-10 days	12.5-23.5 °C
Small-mouth buffalo	*Ictiobus bubalus*	No	Yes	April through September	submerged terrerstrial vegetation during high waters, over all substrates	shallow	7-14 days	19-27.5 °C
Striped bass	*Morone saxatilis*	Yes	No	spring	streams with strong, turbulent flows, rock/fine gravel substrate	near surface	34-62 hours	10-24 °C
Threadfin shad	*Dorosoma petenense*	No	No	spring through	open water, along shorelines over aquatic	shallow	3-4 days	21-26 °C

Fish species	Scientific Name	Game Fish	NM Native	Spawning period	Spawning habitat	Spawning depth	Hatch Time	Spawning temp.
				summer	vegetation			
Walleye	*Stizostedion vitreum*	Yes	No	mid-March through mid-April	1-4 m of shallow areas, riprap on dam faces	1-4m	6-50 days	8.9-12 °C
White bass	*Morone chrysops*	Yes	Yes	spring	rocky, steep shore areas and inlets	2-3m	~2 days	13-17 °C
White crappie	*Pomoxis annularis*	Yes	No	May through July	low velocity, moderate turbidity waters with aquatic vegetation, flooded areas of reservoirs	< 1.5m	27-93 hours	14-23 °C
White sucker	*Catostomus commersoni*	No	Yes	spring through early summer	variety of substrates less than 30 cm in depth, wind swept shores	< 30cm	4-19 days	10+ °C
Yellow perch	*Perca flavescens*	Yes	No	spring	aquatic vegetation, submerged brush, or sand, gravel, rubble substrates	shallow	8-10 days	2.8-18.9 °C

Data Sources: Species Life History Information- Biota Information System of New Mexico. 2001. New Mexico Department of Fish and Game. Online. Available: http://151.199.74.229/states/nmex_main/fish.htm

Northern Section

Platoro Reservoir

Platoro Reservoir is located near the headwaters of the Conejos River, a tributary of the Rio Grande, in south-central Colorado about 1 mile west of Platoro in Conejos County. The Colorado Division of Wildlife stocks Platoro Reservoir with kokanee salmon, brown, and rainbow trout. Other fish species occurring in Platoro reservoir include: Colorado River and Rio Grande cutthroat, brook, and lake trout, white and Rio Grande Sucker, Rio Grande chub, splake, char, and grayling.

Heron Reservoir

Heron Reservoir is located on Willow Creek near the confluence with the Rio Chama, a tributary of the Rio Grande, in north-central New Mexico about 9 miles southwest of Park View in Rio Arriba County.

Heron Reservoir supports a cold-water fishery managed by the U.S. Fish and Wildlife Service (USFWS) and the New Mexico Department of Game and Fish (NMDGF). Important sport fishes include rainbow trout (*Oncorhynchus mykiss*), lake trout (*Salvelinus namaycush*), and Kokanee salmon (*Oncorhynchus nerka*). The USFWS stock rainbow trout in the reservoir in April and August with approximately

400,000 and 200,000 fish stocked respectively each year (Ortiz 2001). Rainbow trout are a put-and-take fishery at Heron Reservoir and the USFWS does not expect any natural reproduction to sustain the rainbow trout population (Ortiz 2001). The NMDGF stock Kokanee salmon in the reservoir with approximately 475,000 fish stocked each year in January (Ortiz 2001).

El Vado Reservoir

El Vado Reservoir is located on the Rio Chama in north-central New Mexico about 160 miles north of Albuquerque in Rio Arriba County.

El Vado Reservoir supports a cold-water fishery with several warm-water species (Ortiz 2001). Cutthroat trout, lake trout, brown trout (*Salmo trutta*), channel catfish (*Ictalurus punctatus*), green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), white crappie (*Pomoxis annularis*), and yellow perch (*Perca flavescens*) are important game species that naturally reproduce in the reservoir (Ortiz 2001). Rainbow trout and Kokanee salmon are stocked annually by the NMDGF with 220,000 and 100,000 rainbow trout stocked in April and October, respectively, and 200,000 Kokanee salmon stocked in January (Ortiz 2001). Rainbow trout in El Vado Reservoir is considered a put-and-take fishery and natural reproduction is not required to sustain populations (Ortiz 2001).

Abiquiu Reservoir

Abiquiu Reservoir is located in north-central New Mexico on the Rio Chama approximately 30 miles west of Española on U.S. highway 84 in Rio Arriba County.

Abiquiu Reservoir supports cold-water fishery consisting of Kokanee salmon, rainbow trout, brown trout, cutthroat trout, and lake trout; and a warm-water fishery consisting of walleye (*Stizostedion vitreum*), green sunfish, largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), white crappie, channel catfish, and bluegill (Ortiz 2001). All of these species have populations in the reservoir that are sustained by natural reproduction except rainbow trout and walleye. Rainbow trout are stocked by the NMDGF in April, October, and November with 100,000; 290,000; and 100,000 fish stocked, respectively (Ortiz 2001). Walleye are occasionally stocked by the NMDGF in April with approximately 1,000,000 fish released (Ortiz 2001).

Central Rio Grande Section

Cochiti Reservoir

Cochiti Reservoir is located on the Rio Grande near the Pueblo de Cochiti Indian Reservation in Sandoval County, New Mexico.

Cochiti Reservoir is primarily a warm-water fishery consisting of northern pike (*Esox lucius*), black bullhead (*Ictalurus melas*), channel catfish, white bass (*Morone chrysops*), striped bass (*Morone saxatillis*), smallmouth bass, largemouth bass, green sunfish, white crappie, black crappie (*Poxomis nigromaculatus*), and bluegill (Ortiz 2001). Cold-water fish species include rainbow trout and brown trout. Walleye are the only species stocked in the reservoir with approximately 1,000,000 fish stocked in April by the NMDGF (Ortiz 2001). Refer to **Table Res 2**. for spawning information on all fish species listed above.

Jemez Canyon Reservoir

Jemez Canyon Reservoir is located on the Jemez River just upstream from its confluence with the Rio Grande in Sandoval County, New Mexico. There is no permanent water in the reservoir and therefore it does not support a sustained fishery (E.W. Jahnke, USACE, personal commmunication 2002).

San Acacia Section

No reservoirs are located within this river section.

Southern Section

Elephant Butte Reservoir

Elephant Butte Reservoir is located on the Rio Grande approximately 4 miles east of Truth or Consequences, Sierra County, New Mexico.

Elephant Butte Reservoir is primarily a warm-water fishery with the exception of rainbow trout and brown trout. Warm-water fish species include white bass, largemouth bass, smallmouth bass, northern pike, bluegill, yellow perch, green sunfish, white and black crappie, channel catfish, black bullhead, and walleye (Ortiz 2001). Striped bass are stocked in the reservoir biyearly by the NMDGF with 300,000 fish stocked in June or July, and yearly by the USFWS with 10,000 fish stocked in June (Ortiz 2001).

Caballo Reservoir

Caballo Reservoir is located on the Rio Grande 25 miles downstream from Elephant Butte Reservoir in Sierra County, New Mexico. The designated uses of the reservoir are irrigation and recreation, and others.

2.5.6 *Zooplankton of Rio Grande Reservoirs*

The two subclasses of Crustaceans that make up a significant portion of the zooplankton biomass in the reservoirs of the Rio Grande are Cladacera and Copepoda. Both range in size from 0.2 – 4 mm long and play an intricate role in the aquatic environment as a base for most food webs. Cladacerans can feed on a variety of food sources including detritus and other smaller organisms such as protozoa and rotifers by means of filtration or generating a current of water over a ciliated food grove. Copepods feed raptoraly either by scraping macrovegitation or by capturing prey and consumption by a chewing mechanism.

Much of the biological activity of a reservoir takes place in the photic zone (the area of the water column that light is able to penetrate) because it supports primary production. This area is within the upper few meters of a water body and commonly is the most populated and diverse environment in lake systems. It is this shallow well-lit environment that is most affected by changing water levels of a reservoir. As the water level drops the areas become shallower and are susceptible to drastic temperature changes and sometimes complete dewatering.

Water temperature and the duration of molting periods of most crustaceans are inversely related. As temperature increases so does an individuals metabolism and so a decrease in the time during and in-between molts is observed. In contrast, colder temperatures slow metabolism and increase the duration of the molting process. Eventually this inverse relationship translates into a faster or slower rate of brood production and is a determining factor in population size. Food availability also plays a significant role in the size and health of the population. As resources increase so does the ability to produce offspring and so brood size increases leading to larger populations. Population size is not only regulated by resource availability but by the amount of predation occurring. Many larval fish feed primarily on zooplankton.

Many of the fish found in the reservoirs of the Rio Grande feed on zooplankton during their larval stages. As a population of zooplankton increases, the ability of fish larvae to survive to reproductive age increases, thus causing an increase in the size of the fish population. As the population of fish increase more larvae consume more zooplankton and thus cause a decrease in the zooplankton population. As zooplankton decline so does the ability of the food base to support the fish populations, and the fish numbers decline.

2.5.7 *The Reservoir Aquatic Food Base*

Abiquiu Reservoir was sampled in 1998, 2000, and 2001 (NMDGF 2003a unpublished data). Results indicate the highest number of total Cladocera were from 2001. The lowest numbers of Cladocera were from 2000. Copepods in Abiquiu Reservoir were at their highest in 1998 and their lowest in 2001 (**Table L-2.16**).

Caballo Reservoir was sampled for zooplankton in 1998 and 2000 (NMDGF 2003a unpublished data). Results indicated that the populations of Cladocera and Copepods were much greater in 2000 than in 1998 (**Table L-2.16**).

Cochiti Reservoir was sampled in 2000 and 2001 (NMDGF 2003a unpublished data) and results indicated that populations of Cladocera and Copepods were much greater in 2001 than in 2000 (**Table L-2.16**).

Elephant Butte was only sampled in 2001 (NMDGF 2003a unpublished data), but populations of both Cladocera and Copepods were high compared to results from other reservoirs (**Table L-2.18**).

Heron Reservoir was sampled every year from 1998 to 2001 (NMDGF 2003a unpublished data). Results indicate that Cladocera populations were at their highest in 1998 and their lowest in 1999. Copepod populations were at their highest in 2001 and their lowest in 1999 (**Table L-2.16**).

Heron Reservoir was the only site to have samples taken consistently for four years and therefore the most useful to look for patterns in zooplankton population. Other sites were sampled sporadically throughout the four-year period and so do give an idea as to zooplankton populations, but is not useful in determining patterns of the populations. It is assumed that the higher number of zooplankton would be able to support a larger population of fish and so Caballo and Elephant Butte should be more productive than the other sites being that they had the some of the largest number of plankton. Zooplankton blooms can give clues as to what is happening within the reservoir either being attributed to an abundance of resources or the decline or removal of a predator (i.e. fish and fish larva).

Table L-2.16 Zooplankton Populations for Five Rio Grande Reservoirs from 1998-2001 (NMDGF 2003a Unpublished Data; Personal Communication)

Reservoir	Adult Cladocera (Org/L)	Immature Cladocera (Org/L)	Total Cladocera (Org/L)	Adult Copepod (Org/L)	Immature Copepod (Org/L)	Total Copepod (Org/L)
Abiquiu						
1998	277,333	366,556	643,889	3,234,194	1,934,861	5,169,056
1999	Ø	Ø	Ø	Ø	Ø	Ø
2000	171,528	142,139	313,667	1,298,472	953,611	2,252,083
2001	2,728,125	822,500	3,550,625	916,875	157,500	1,074,375
Caballo						
1998	735,500	526,611	1,262,111	3,807	3,733,528	3,737,334
1999	Ø	Ø	Ø	Ø	Ø	Ø
2000	940,185	1,045,741	1,985,926	1,528,148	1,515,925	3,044,074
2001	Ø	Ø	Ø	Ø	Ø	Ø
Cochiti						
1998	Ø	Ø	Ø	Ø	Ø	Ø
1999	Ø	Ø	Ø	Ø	Ø	Ø
2000	105,722	85,833	191,556	479,139	392,639	871,778
2001	1,023,854	498,993	1,522,847	1,555,910	888,333	2,444,243
Elephant Butte						
1998	Ø	Ø	Ø	Ø	Ø	Ø
1999	Ø	Ø	Ø	Ø	Ø	Ø
2000	Ø	Ø	Ø	Ø	Ø	Ø
2001	3,733,111	2,266,069	5,999,181	20,162,208	23,399,250	43,561,458
Heron						
1998	1,983,306	717,472	2,700,778	1,918,000	694,472	2,612,472
1999	108,333	5,694	114,028	584,306	146,806	731,111
2000	251,667	187,917	439,583	1,272,639	1,554,167	2,826,806
2001	1,301,892	373,646	1,675,538	3,159,878	1,634,861	4,794,740

Ø No Data Available; indicates no sampling conducted

2.5.8 *Terrestrial Riparian Fauna*

2.5.8.1 Riparian Fauna Characterization Methods

In order to establish a baseline of the general fauna within the Project Area, the Riparian Team sought prior surveys that could help identify those species known to utilize the riparian corridor. Most mammal, amphibian, reptile, and arthropod species are considered to be permanent residents. However, bird species include both year-round residents and those neotropicals whose nesting activities may only place them in the area for three to five months each year. There are on-going, long-term studies of federally listed species, particulary those deemed endangered. However, because no on-going, year-round studies have been performed, general wildlife usage of the area is based upon "spot" surveys throughout recent decades. These surveys include Stahlecker and Cox (1996) for bird populations; Campbell et al. (1997) for mammal information, and Hink and Ohmart (1984) for all wildlife families. The Hink and Ohmart (1984) data were particularly useful in that they establish the correlation between vegetation types (shown in Figure L-2.2) and terrestrial wildlife species richness, composition, and habitat associations (see **Table L-2.2** in section 2.3.1.4). This knowledge of which vegetation types support the greatest biodiversity forms the baseline for assessing potential impacts on riparian fauna in Chapter 3, Section 3.4 of this Biological Technical Report.

2.5.8.2 Overview of General Wildlife Use of Riparian Zones within the Rio Grande Floodplain

Riparian ecosystems play a vital role in determining wildlife abundance and diversity, particularly in arid areas that may otherwise be treeless and frequently devoid of surface water. The Rio Grande Floodplain ecosystems included in this study contribute significantly to regional wildlife even though they make up less than 1% of the land area of the Basin (Finch et al. 1995). Also contributing to the function of the Rio Grande riparian ecosystems for supporting biodiversity is the fact that it spans several geophysical provinces. It also provides a valuable migratory corridor for the long-distance migration of birds.

A broad network of wildlife species contributes to the overall function of the Rio Grande floodplain ecosystem. First and foremost, the floodplain provides wildlife with a reliable source of surface water. Section 2.3.2.3 detailed the vegetation communities found along the Rio Grande Corridor, most of which are diverse communities with native vegetation highly desirable to wildlife species for food and cover. A rich community of invertebrates proliferates in the moist habitats along the shoreline in the flooded areas and perennial wetlands in the floodplain corridor (Gaston 1991). The plant and insect biomass of the riparian area, in turn, attracts and supports numerous diverse higher order organisms, some obligate residents of the ecosystem and others using the area during their unique diurnal or seasonal cycles.

Plant species are not the only part of the ecosystem that may be obligate to riparian zones. Habitat specialists, such as the willow flycatcher (*Empidonax trailli*), Lincoln's sparrow (*Melospiza lincolnii*), and white-crowned sparrow (*Zonotrichia leucophrys*) depend on healthy riparian vegetation (Knopf et al. 1988a). The New Mexico meadow jumping mouse, state-listed as a threatened species, requires soil moisture and vegetation characteristics related to permanent water availability (NMDGF 2004b). While the causes for the global decline of many amphibian species are unknown, what is known is that most require permanent to semi-permanent water habitats and their associated vegetation cover. The New Mexico state-endangered lowland leopard frog (*Rana yavapaiensis*) requires such habitat at low elevations in desert scrub localities (Platz 1988). Invertebrates such as the endangered wrinkled marshsnail have been extirpated from some areas in New Mexico because of extensive wetland habitat loss and alteration (Taylor 1983) or contamination of water habitats by sewage NMDGF 2002).

Many wildlife species rely on riparian habitats, not just those listed as threatened or endangered. Additionally, while native riparian vegetation is obligate to river corridors, this is not necessarily the case for the wildlife species associated with these habitats. Wharton et al. 1982 (Schaefer and Brown 1992) pointed out that animals do not occur in distinct zones or patterns in the same manner in which vegetation zones appear. When factors such as bird migration are considered, it is clear that a permanent zone cannot be assigned to all wildlife species. Many terrestrial species roam over large territories and may be found in riparian zones only during certain seasons. This does not make them any less dependent upon riparian vegetation, nor does it lessen their effect upon riparian habitat.

Schaefer and Brown (1992) provide a brief, but succinct, description of riparian habitats and the wildlife that utilize them:

> Many wildlife species contribute to the ecological function of riparian communities, albeit very few are restricted to them. The use of riparian zones by wildlife differs by species, season, and flooding regime. Bears travel over large areas and seasonally forage on fish and aquatic plants. Most wading birds prey on aquatic organisms and nest in uplands. Many terrestrial birds nest close to streams and rivers, and forage over large areas including, but not confined to, the wetlands of these water bodies. Semiaquatic turtles typically nest in sandy uplands that can be several hundred meters from the water's edge. Other species respond to seasonal differences of plant mast production by concentrating feeding activities in wetlands during winter and spring and drier sites during summer and fall.

An animal that forages in riparian vegetation will distribute seed via fecal material or by transporting it on their fur. This contributes to genetic diversity and range expansion by riverine plants. Fossorial mammals, reptiles, and amphibians turn the soil during burrowing activities. This activity helps incorporate leaves, deadfall, and other organic material into the soil, while the ground becomes more friable and receptive to scattered seeds. Collectively, mammals, reptiles, and birds eat plants, disperse seeds, and move soils—activities that alter vegetative structure, modify channel morphology, and assist in developing microtopography. Such actions go far beyond mere forage or habitat needs, creating consequences at the ecosystem level (Naiman and Rogers 1997). In a cyclic manner, animal activities return nutrients to the soil, which becomes available for intake by the vegetation, which is returned to wildlife species via foliage. A symbiotic relationship exists between wildlife and riparian habitat. The cycles come full circle when riparian vegetation furnishes forage, protection, roosting, and nesting habitat for innumerable terrestrial species.

There is a large body of literature that describes the intimate relationship between riparian corridors and the wildlife that fills each available niche. A variety of studies have focused on wildlife specifically utilizing habitat along the Rio Grande floodplain. Changing the local hydrology, as proposed by the project, will only indirectly affect wildlife by changing the hydrological support for favored vegetation communities or structure. Hink and Ohmart (1984) found that faunal abundance and composition varied with vegetation community composition and structure in the Rio Grande Valley. The relationship of fauna to specific vegetation communicates in the Rio Grande Valley is described here as a resource indicator.

Insects

Little data exist concerning terrestrial arthropod communities for the arid southwest, particularly within riparian ecosystems. It is known that arthropods, both in number of species and individuals, dominate terrestrial ecosystems (Wilson 1988; Kremen et al. 1993). Terrestrial arthropods may act as pollinators, herbivores, detrivores, parasites, or predators. Their activities influence nutrient cycling and plant productivity. They also contribute to the abundance of other invertebrates as well as many vertebrates, for whom they are prey species (Ellis et al. 2000). Surface arthropods are at the foundation of vertebrate trophic levels. Studies by Knopf et al. (1988b) and Ohmart and Anderson (1982) indicate that the riparian areas in the arid southwestern United States support a disproportionately higher density and diversity of vertebrates when compared with drier uplands.

The Middle Rio Grande Valley has been the focus of the majority of arthropod studies. A 1994-1997 study (Bess et al. 2002) found 80 species on the forest floor. These species were predominantly spiders (Lycosidae, Gnaphosidae, Salticidae), beetles (Carabidae, Staphylinidae, Crytophagidae, Tenebrionidae), isopods (Armadillidae, Porcellionidae), and crickets (Gryllidae). Ellis et al. (2000) found 138 taxa from four sites along the middle Rio Grande. In a 2001 study, Ellis et al. found that the isopod *Armadillidium vulgare*, known to most as a "roly-poly bug," was the most common taxon at their study sites. A variety of ant species are also found in riparian ecosystems (Eichhorst et al. 2000; Ellis et al. 2001; Bess et al. 2002). It is an important note that surface arthropods can be caught in pit-fall traps, and thereby classified taxonomically. Flighted insects are not easily caught or categorized. Nonetheless, riparian ecosystems also support many flying insect species, desireable to numerous vertebrate species at higher trophic levels.

There are reptile, amphibian, mammal, and bird species that are obligate insectivores, and many others that utilize insects as some portion of their diet. Granivores, such as sparrows and finches, depend on insects as a source of protein to feed nestlings. Even hummingbirds, known for their attraction to nectar, depend upon insects for protein and amino acids. An adult hummingbird can ingest 400-600 fruit flies, midges, and leaf-hoppers each day (E. P. Elliston, Wildlife Rescue, Inc. of New Mexico, personal communication 2003). In a healthy riparian ecosystem, heterogeneity of plant species, age, and height classes will support the diversity of insect life so foundational to all species that utilize riparian habitats. However, at present, insect abundance and diversity has not been linked to specific Hink and Ohmart vegetation communities found in the Rio Grande.

Amphibians and Reptiles

Beiswenger (1988) discussed the fact that many monitoring and assessment models were developed for either terrestrial or aquatic species and have not been adapted for species with divergent lifecycles that depend on both habitat forms. Additionally, amphibians have complex life cycles and secretive habits during the breeding season, making them relatively difficult to study. The distribution of several amphibian and reptile species in New Mexico is closely correlated to riparian vegetation communities. Degenhardt et al. (1996) stated:

> "All amphibians in New Mexico except *Aneides hardii* (Sacramento mountain salamander), *Plethodon neomexicanus* (Jemez Mountains salamander), *and Eleutherodactylus augusti* (barking frog) require temporary or permanent water for breeding. All turtles in the state except *Terrapene ornate* (ornate box turtle) are aquatic or semiaquatic, and all except *Kinosternon flavescens* (yellow mud turtle) and *T. ornate* do not wander far from water. Several snakes are largely riparian… including *Nerodia erythrogaster* (plainbelly water snake), *Thamnophis cyrtopsis* (blackneck garter snake), *T. eques* (Mexican garter snake), *T. marcianus* (checkered garter snake), *T. proximus* (western ribbon snake), *T. rufipunctatus* (narrowhead garter snake), and *T. sirtalis* (common garter snake)."

In their studies of wildlife use of riparian communities along the Middle Rio Grande, Hink and Ohmart (1984) identified the following class-specific pattern:

Amphibian and reptile capture rates were highest in sites with sandy soils, sparse ground cover, and relatively open vegetation. Such sites include areas of mixed 20- to 40-foot cottonwood/coyote willow stands with sparse understory, open drain habitats dominated by cottonwoods and willows less than 15 feet tall, and small openings with little or no woody species. Hink and Ohmart also reported that capture rates were lowest in sites with dense understories, particularly in marshy, edge, and wooded areas with stands of Russian olive or herbaceous species.

Avian

Birds are the most visible and, therefore, the most widely studied wildlife in the Rio Grande floodplain. At least 510 bird species are confirmed in New Mexico, some 300 of which breed in the state (Williams 2004). Although limited in areal extent, the riparian community along the Rio Grande is utilized by over

60% of the bird species known to occur in New Mexico Hink and Ohmart (1984) Among the most common species during the breeding season are mourning dove, black-chinned hummingbird, downy woodpecker, ash-throated flycatcher, white-breasted nuthatch, spotted towhee, black-headed grosbeak, and blue grosbeak. Common breeding raptors include great horned owl, western screech-owl, Cooper's hawk, and, in burned areas, American kestrel.

Generally, the abundance of breeding birds increases with the complexity and density of vegetation structure, which is thought to be related to the increased food, cover, or nest substrate it provides. Along the Rio Grande, the highest breeding densities typically have been found in cottonwood stands with a well developed shrub understory (Type 1) and in tall shrub stands (Type 5), regardless of whether the shrubs are native or exotic (H&O 1984; Hoffman 1990, Thompson et al, 1994, Stahlecker and Cox 1996). Within this woodland type, avian abundance is approximately four times greater along the riverward and landward edges of the bosque, than in the interior of the stand (H&O 1984). Bosque stands with a sparse understory (Type 2) generally support fewer breeding birds. Stands of intermediate age or structure (Types 3 and 4) vary widely in breeding bird use among the studies conducted (Farley et al. 1994a), but, in light of the general lack of natural cottonwood and willow regeneration along the Rio Grande, are important for their potential to develop into mature stands. Salt cedar stands (with or without a cottonwood canopy) have relatively low breeding bird use.

The Rio Grande is a major migratory corridor for songbirds (Yong and Finch 2002), waterfowl, and shorebirds. Both the river channel and the drains adjacent to the bosque provide habitat for species such as mallards, wood ducks, great blue herons, snowy egrets, green herons, belted kingfishers and black phoebes. Agricultural fields and grassy areas with little woody vegetation are important food sources for sparrows and other songbirds during migration and winter.

Birds may be the most studied wildlife at the habitat level, perhaps because of the popularity of birding. Lying along the westernmost edge of “the Central Flyway,” the Rio Grande is a major migratory corridor, thus supporting both resident and neotropical species. Monson (1946) surveyed the avifauna of the Rio Grande Valley, focusing on cottonwood bosques—an early acknowledgment that certain species require distinct vegetation and habitat types. Carothers (1994) studied the social organization and population structure of riparian birds in the Southwest. Carothers found that differences in species’ density were, in part, related to the vegetative structure of the habitat.

Some avian vegetation-use surveys focus on specific taxonomic orders. Raptors have been studied based on vegetation choices for nesting, perching, and hunting territories, and even route choice between such areas. Kimsey and Conley (1986) looked at both seasonal and annual habitat selection in southwestern New Mexico. They found that the red-tailed hawk (*Buteo jamaicensis*) and ferruginous hawk (*Buteo regalis*), as well as the American kestrel (*Falco sparverius*), selected riparian habitats. In a survey of active nest sites in the Jemez Mountains of New Mexico, Kennedy (1986) found that about 17% of the area’s Cooper’s hawks (*Accipiter cooperii*) chose Rio Grande cottonwood (*Populus fremontii*) or Cottonwood-ponderosa pine (*P. fremontii – Pinus ponderosa*).

Farley et al. (1994a) stated:

> “The presence of foliage in various height classes, the diversity of plant species and forms, the heterogenous mix of open and densely vegetated areas, and the relatively high frequency of nesting cavities all combine to form a complex association that can support a variety of avian species. These corridors of woody vegetation also appear to be important for migrant landbirds, including both species that overwinter in the Neotropics and short-distance migrants that usually winter in the southern United States…”

Partners in Flight (2003), dedicated to the conservation of avian diversity, confirm that New Mexico’s riparian areas are among the most species-rich habitats in the state. The continual presence of water—and the resulting structural complexity—allows riparian areas to support a higher percentage of breeding species than does other habitats. The group establishes a "priority" status for birds based on vegetation type. As the largest river in New Mexico, the Rio Grande exhibits the majority of Middle-Elevation Riparian Woodland in the state. Partners in Flight have categorized the birds associated with various riparian plant species and height classes. These bird/plant associations are confirmed in a variety of studies.

The results of a 1992 study (Farley et al. 1994b), documenting vertebrate use of riparian vegetation in the Middle Rio Grande Valley, indicate that riparian woodlands of different age (and therefore height classes) support different assemblages of bird species. This study, and others, only confirms the findings in Hink and Ohmart's (1984) study—possibly the seminal work correlating riparian vegetation to terrestrial vertebrate habitat use. They found that birds were the largest and most diverse group of terrestrial fauna in the riparian study area.

Hink and Ohmart (1984) utilized four main vegetation groups: C/CW (cottonwood/coyote willow); C/RO (cottonwood, Russian olive); RO (Russian Olive); and MH (marsh). They recorded 277 avian species over the two years of the study, 60% of the number of bird species known to occur in New Mexico at that time (Hubbard 1978). Most of these species were primarily associated with riparian shrub or forest habitats; a complete listing is not warranted herein. However, a sampling indicates the wide range of trophic levels represented. The most common species range from aquatic piscivores and herbivores through terrestrial granivores, omnivores, carnivores, and obligate insectivores. It must be noted that the presence of certain species may not reflect those common at present, twenty years after Hink and Ohmart's study. Leal et al. (1996) found that the bird species composition in 1992-1993 was similar to historically documented composition. This study found the highest species richness and abundance in cottonwood and willow, but documented considerable bird use in exotic stands.

In the context of the importance of heterogeneity of riparian plant species and height classes, Hink and Ohmart's (1984) findings can be applied to some extent outside of the Middle Rio Grande area of this study. For instance, the C/CW (cottonwood/coyote willow) structure will be similar in Reaches 1 through 4, even though these northernmost areas are narrowleaf cottonwood (*Populus angustifolia*) rather than the broadleaf species seen in the Middle Rio Grande floodplain. If deciduous trees and snags afford excavation sites for cavity dwellers, various woodpecker species can be expected. Hairy (*Picoides villosus*) and downy woodpeckers (*P. pubescens*) will be present, as well as various flycatchers and other birds that utilize cavities excavated by piciformes.

In spring and summer, Hink and Ohmart found that the two most common species in the cottonwood forest types were the mourning dove (*Zenaida macroura*) and black-chinned hummingbird (*Archilochus alexandri*). Other common species included Gambel's quail (*Callipepla gambelii*), northern flicker (*Colaptes auratus*), ash-throated flycatcher (*Myiarchus cinerascens*), ring-necked pheasant (*Phasianus colchicus*), the introduced European starling (*Sturnis vulgaris*), American robin (*Turdus migratorius*), northern oriole (*Icterus galbula*), black-headed grosbeak (*Pheucticus melanocephalus*), lesser goldfinch (*Carduelis psaltria*), rufous-sided [spotted] towhee (*Pipilo maculates*), and brown-headed cowbird (*Molothrus ater*).

Community structures that included open water also attracted a distinct set of species. In addition to mallards, the American robin and red-winged blackbird (*Agelaius phoeniceus*) were the most common species in spring and summer, and belted kingfishers (*Ceryle alcyon*) and black phoebes (*Sayornis nigricans*) were also found. Black-crowned night herons (*Nycticorax nycticorax*), snowy egrets (*Egretta thula*), green herons (*Butorides virescens*), and great blue herons were also associated with these areas.

Three sites were chosen along the Rio Grande at which to compare breeding birds known to utilize the Rio Grande migratory corridor (**Table L-2.17**). Alamosa National Wildlife Refuge lies in Reach 1; the Bosque del Apache NWR is within Reach 14; and the Rio Bosque Wetlands Park in El Paso, Texas, is at the northernmost end of Reach 17.

Hink and Ohmart (1984) also categorized wintering avian species. The winter residents, arriving in the fall at cottonwood habitats, included white-crowned sparrow (*Zonotrichia leucophrys*), dark-eyed juncos (*Junco hyemalis*), hermit thrushes (*Catharus guttatus*), ruby-crowned kinglets (*Regulus calendula*), yellow-rumped warblers (*Dendroica coronata*), brown creepers (*Certhia Americana*), Bewick's wrens (*Thryomanes bewickii*), song sparrows (*Melospiza melodia*), and large flocks of American crows (*Corvus brachyrhynchos*).

The majority of raptor species were fall migrants or winter residents. These include the northern harrier (*Circus cyaneus*), sharp-shinned hawk (*Accipiter striatus*), red-tailed hawk (*Buteo jamaicensis*), ferruginous hawk (*B. regalis*), rough-legged hawk (*B. lagopus*), and bald eagle (*Haliaeetus leucocephalus*). Five species were present during summer surveys: the turkey vulture (*Cathartes aura*), osprey (*Pandion haliaetus*), Mississippi kite (*Ictinia mississippiensis*), American kestrel (*falco sparverius*), and prairie falcon (*Falco mexicanus*). Cooper's hawks (*Accipiter cooperii*) were seen during all seasons.

Table L-2.17 Area Comparison of Breeding Bird Species Found in Riparian Zone at Three Selected Locations from Alamosa, Colorado to El Paso, Texas

Codes represent: **B** = Commonly breeds at site; □ = present but does not commonly breed;
✕ = Not present at site during breeding season

River Section:		**Northern**	**San Acacia**	**Southern**
Family/Common Name	Taxonomic Name	Alamosa NWR[1]	Bosque del Apache NWR[2]	Rio Bosque Wetlands Park[3]
PODICIPEDIDAE				
Pied-billed grebe	*Podilymbus podiceps*	B	B	□
ARDEIDAE				
Great blue heron	*Ardea herodias*	□	B	□
Snowy egret	*Egretta thula*	B	B	B
Green heron	*Butorides virescens*	□	B	□
Cattle egret	*Bubulcus ibis*	□	□	B
Black-crowned night heron	*Nycticorax nycticorax*	B	B	B
THRESKIORNITHIDAE				
White-faced ibis	*Plegadis chihi*	B	B	□
CATHARTIDAE				
Turkey vulture	*Cathartes aura*	□	B	B
ANATIDAE				
Canada goose	*Branta canadensis*	B	B	✕
Gadwall	*Anas strepera*	B	B	□
Mallard	*Anas platyrhynchos*	B	B	□
Blue-winged teal	*Anas discors*	B	B	□
Cinnamon teal	*Anas cyanoptera*	B	B	□
Northern shoveler	*Anas clypeata*	B	B	□

River Section:		Northern	San Acacia	Southern
Family/Common Name	Taxonomic Name	Alamosa NWR[1]	Bosque del Apache NWR[2]	Rio Bosque Wetlands Park[3]
Northern pintail	*Anas acuta*	B	B	□
Green-winged teal	*Anas crecca*	B	B	□
Redhead	*Aythya americana*	B	B	□
Ruddy duck	*Oxyura jamaicensis*	B	B	□
ACCIPITRIDAE				
Red-tailed hawk	*Buteo jamaicensis*	B	B	×
Swainson's hawk	*Buteo swainsonii*	B	□	□
Northern harrier	*Circus cyaneus*	B	B	□
Cooper's hawk	*Accipiter cooperii*	□	B	□
FALCONIDAE				
American kestrel	*Falco sparverius*	B	B	□
PHASIANIDAE				
Ring-necked pheasant	*Phasianus colchicus*	B	B	×
ODONTOPHORIDAE				
Gambel's quail	*Callipepla gambelii*	×	B	B
RALIDAE				
Virginia rail	*Rollus limicola*	B	□	×
Sora	*Porzana Carolina*	B	B	□
Common moorhen	*Gallinula chloropus*	×	□	B
American coot	*Fulica americana*	B	B	□
CHARADRIIADAE				
Killdeer	*Charadrius vociferous*	B	B	B
RECURVIROSTRIDAE				
Black-necked stilt	*Himantopus mexicanus*	□	B	□
American avocet	*Recurvirostra americana*	B	B	□
SCOLOPACIDAE				
Spotted sandpiper	*Actitis macularia*	B	B	□
Common snipe	*Gallinago gallinago*	B	×	×
Wilson's phalarope	*Phalaropus tricolor*	B	□	□
COLUMBIDAE				
Mourning dove	*Zenaida macroura*	B	B	B
CUCULIDAE				
Greater roadrunner	*Geococcyx californianus*	×	B	B

River Section:		Northern	San Acacia	Southern
Family/Common Name	Taxonomic Name	Alamosa NWR[1]	Bosque del Apache NWR[2]	Rio Bosque Wetlands Park[3]
STRIGIDAE				
Great horned owl	*Bubo virginianus*	B	□	×
Burrowing owl	*Athene cunicularia*	□	□	B
Short-eared owl	*Asio flammeus*	B	□	×
CAPRIMULGIDAE				
Lesser nighthawk	*Chordeiles acutipennis*	×	B	□
Common nighthawk	*Chordeiles minor*	B	B	□
APODIDAE				
Black-chinned hummingbird	*Archilochus alexandrii*	□	B	B
PICIDAE				
Ladder-backed woodpecker	*Picoides scalaris*	×	B	□
Northern flicker	*Colaptes auratus*	□	B	×
TYRANNIDAE				
Western wood pewee	*Contopus sordidulus*	□	B	□
Black phoebe	*Sayornis nigricans*	×	B	□
Say's phoebe	*Sayornis saya*	□	B	×
Ash-throated flycatcher	*Myiarchus cinerascens*	×	B	□
Western kingbird	*Tyrannus verticalis*	□	B	B
CORVIDAE				
Black-billed magpie	*Pica hudsonia*	B	□	×
Chihuahuan raven	*Corvus cryptoleucus*	×	B	□
ALAUDIDAE				
Horned lark	*Eremophila alpestris*	B	□	×
HIRUNDINIDAE				
Northern rough-winged swallow	*Stelgidopteryx serripennis*	□	B	□
Tree swallow	*Tachycineta bicolor*	B	B	□
Barn swallow	*Hirundo rustica*	B	B	□
Cliff swallow	*Petrochelidon pyrrhonota*	B	B	□
REMIZIDAE				
Verdin	*Auriparus flaviceps*	×	□	B
TROGLODYTIDAE				
Bewick's wren	*Thryomanes bewickii*	×	B	×

River Section:		Northern	San Acacia	Southern
Family/Common Name	Taxonomic Name	Alamosa NWR[1]	Bosque del Apache NWR[2]	Rio Bosque Wetlands Park[3]
Marsh wren	*Cistothorus palustris*	B	□	×
MIMIDAE				
Northern mockingbird	*Mimus polyglottos*	□	B	B
Sage thrasher	*Oreoscoptes montanus*	B	□	□
Crissal thrasher	*Toxostoma crissale*	×	□	□
TURDIDAE				
American robin	*Turdus migratorius*	B	B	×
STURNIDAE				
European starling	*Sturnis vulgaris*	B	B	□
PARULIDAE				
Yellow-rumped warbler	*Dendroica coronata*	B	□	×
Common yellowthroat	*Geothlypis trichas*	B	B	□
Yellow-breasted chat	*Icteria virens*	×	B	B
EMBERIZIDAE				
Cassin's sparrow	*Aimophila cassinii*	□	□	□
Vesper sparrow	*Poocetes gramineus*	B	□	×
Savannah sparrow	*Passerculus sandwichensis*	B	□	×
Song sparrow	*Melospiza melodias*	B	□	×
CARDINALIDAE				
Black-headed grosbeak	*Pheuticus melanocephalus*	□	B	×
Blue grosbeak	*Guiraca caerulea*	□	B	□
Painted bunting	*Passerina ciris*	×	×	B
ICTERIDAE				
Red-winged blackbird	*Agelaius phoeniceus*	B	B	□
Western meadowlark	*Sturnella magna*	B	B	×
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	B	□	□
Brewer's blackbird	*Euphagus cyanocephalus*	B	□	×
Great-tailed grackle	*Quiscalus mexicanus*	□	B	□
Brown-headed cowbird	*Molothrus ater*	B	B	□
FRINGILLIDAE				
House finch	*Carpodacus mexicanus*	B	B	B
Lesser goldfinch	*Carduelis psaltria*	□	B	□

River Section:		Northern	San Acacia	Southern
Family/Common Name	Taxonomic Name	Alamosa NWR[1]	Bosque del Apache NWR[2]	Rio Bosque Wetlands Park[3]
American goldfinch	*Carduelis tristis*	B	□	×
PASSERIDAE				
House sparrow	*Passer domesticus*	B	B	□

SOURCES: [1] USFWS 2003a; [2] USGS Website (USGS 2003b); [3] Rio Bosque Wetlands Park (2003)

Drain and sandbar/river channels in fall and winter showed a distinctive complement of species. Ducks included mallards (*Anas platyrhynchos*), cinnamon teal (*A. cyanoptera*), American wigeon (*A. Americana*), gadwall (*A. strepera*), and northern shoveler (*A. clypeata*). Great blue herons (*Ardea herodias*), water pipits (*Anthus spinoletta*), and mountain bluebirds (*Sialia currucoides*) were found along the sandbars.

The same three sites were reviewed for avian species that were distinctly related to wintering activities. A selection of those species appears in **Table L-2.18**.

It has already been pointed out that, in general, more survey information is available for avian species than any other. **Table L-2.17** and **Table L-2.18** illustrate another important point: avian riparian habitat usage cannot be assigned a permanent zone. There is a distance of approximately 390 miles from the northern to southern sites—and climatic and geomorphic differences range from the 7,500-foot San Luis Valley floor, through steep, rocky canyons such as the Rio Grande Gorge north of Taos, New Mexico, on down to extremely arid high- and low-desert portions of New Mexico and Texas. Nonetheless, there is considerable similarity of breeding species at all three sites represented in **Table L-2.18**. Conversely, the main wintering species shown in **Table L-2.17**clearly indicate that some species are never present, at any season, in the northern- and southernmost sites. The riparian habitat provided by the Rio Grande is a dynamic system along its entire length. Wildlife usage, as indicated by the avian species in **Table L-2.17** and **Table L-2.18**, is dynamic as well and cannot be relegated to simple, linear territories.

Small Mammals

In riparian habitats, small mammals are generally rodents, most often mouse and rat species. In a study of desert rodent communities, Bowers et al. (1987) discuss the need to view habitat use by rodents at the microhabitat level. Beyond a preference for riparian vegetation, for instance, will be their need for small areas of dense groundcover. This will provide more potential for escape from visually oriented predators. Such studies confirm the need for a healthy, native understory as well as for a mixed-age canopy.

Hink and Ohmart (1984) found small mammal capture rates were highest in sites with cottonwood and coyote willow less than 40-feet tall with a relatively dense understory. Many of these high-capture sites were in edge areas or adjacent to open water. Moderate capture rates were also achieved in these communities, as well as in dense understories along the edges of cottonwood/coyote willow woodlands taller than 40 feet, and in various open, woody, and marshy areas with woody species less than 15 feet tall and little or no understory. Capture rates were lowest in areas where trees were over 20 feet tall with limited understory vegetation. Three years of experimental flooding had no apparent effect on the rodent population in riparian habitats within Bosque del Apache NWR (Ellis et al. 1996). During this study, white-footed mice (*Peromyscus leucopus*) were observed to occupy trees and shrubs during floods.

Large Mammals

Large animals can significantly modify the structure and function of river corridors, as discussed by Naiman and Rogers (1997). The designation of 'large' should not be mistakenly limited to deer, elk, bear, cougar, and so forth. Many riparian studies, such as Campbell et al. (1997) include raccoon, beaver, coyote, and other mammals that are too large to be captured in conventional live traps. Medium-sized diurnal mammals such as cottontail rabbit or rock squirrel, which are more often seen than trapped, were also placed in the ‘large’ category by the Campbell study. Much of the mammal diversity in riparian habitats is evidenced by sign: Tracks, scat, burrows, scent, or vocalizations verify presence even if the animal itself is not observed or trapped.

Table L-2.18 Comparison of Selected Wintering Migrant Bird Species Found in Riparian Zone at Three Selected Locations from Alamosa, Colorado to El Paso, Texas

Codes represent wintering status: □ = Abundant or common during winter;
× = Not present or rare at site during winter; ◘ = Not present any season

River Section:		Northern	San Acacia	Southern
Family/Common Name	Taxonomic Name	Alamosa NWR[1]	Bosque del Apache NWR[2]	Rio Bosque Wetlands Park[3]
ARDEIDAE				
Great egret	*Ardea alba*	×	×	□
ANATIDAE				
Snow goose	*Chen caerulescens*	×	□	×
Ross’ goose	*Chen rossii*	×	□	◘
Gadwall	*Anas strepera*	×	□	□
American wigeon	*Anas Americana*	×	×	□
Ring-necked duck	*Aythya collaris*	×	□	×
Bufflehead	*Bucephala albeola*	×	□	×
Common merganser	*Mergus merganser*	×	□	◘
ACCIPITRIDAE				
Bald eagle	*Haliaeetus leucocephalus*	□	□	×
Sharp-shinned hawk	*Accipiter striatus*	×	□	×
Rough-legged hawk	*Buteo lagopus*	□	×	◘
GRUIDAE				
Sandhill crane	*Grus canadensis*	×	□	×
PICIDAE				
Northern flicker	*Colaptes auratus*	×	□	□
CORVIDAE				
American crow	*Corvus brachyrhynchos*	×	□	□
Chihuahuan raven	*Corvus cryptoleucus*	◘	×	□
TYRANNIDAE				
Say’s phoebe	*Sayornis saya*	×	□	□
TROGLODYTIDAE				
Marsh wren	*Cistothorus palustris*	×	□	×
REGULIDAE				
Ruby-crowned kinglet	*Regulus satrapa*	×	□	□
MOTACILLIDAE				

River Section:		Northern	San Acacia	Southern
Family/Common Name	Taxonomic Name	Alamosa NWR[1]	Bosque del Apache NWR[2]	Rio Bosque Wetlands Park[3]
American pipit	*Anthus rubescens*	×	□	×
PARULIDAE				
Yellow-rumped warbler	*Dendroica coronata*	×	×	□
EMBERIZIDAE				
American tree sparrow	*Spizella arborea*	□	×	◘
Savannah sparrow	*Passerculus sandwichensis*	×	×	□
Song sparrow	*Melospiza melodias*	□	□	□
White-crowned sparrow	*Zonotrichia leucophrys*	×	□	□
Dark-eyed junco	*Junco hyemalis*	□	□	
FRINGILLIDAE				
Pine siskin	*Carduelis pinus*	×	□	◘
American goldfinch	*Carduelis tristis*	×	□	◘

SOURCES: [1] USFWS 2003a; [2] USGS Website (USGS 2003b); [3] Rio Bosque Wetlands Park (2003)

For purposes of their analyses, Hink and Ohmart (1984) placed all mammal species larger than rats in the category of large mammals. Consequently, this grouping includes a sizeable range of species from squirrels to domestic livestock. Of these, aquatic species such as beaver (*Castor canadensis*) and muskrat (*Ondontra zibethicus*) were naturally found near open water sources. Though rarely seen, based on the frequent occurrence of tracks and other identifiable signs, raccoons (*Procyon lotor*) were perhaps the most abundant large mammals in the Middle Rio Grande. This species was found along sandbars, drains, marshes, and ponds, as well as mixed cottonwood bosques.

Other large mammal species that were found to be relatively common in the riparian woodlands along the Middle Rio Grande were the porcupine (*Erethizon dorsatum*) and long-tailed weasel (*Mustela frenata*). Though these species are not riparian obligates, they are frequently found in higher concentrations in areas of dense riparian vegetation. Striped skunks (*Mephitis mephitis*) were also commonly found along the Rio Grande, though their occurrence may be more of a consequence of disturbed and developed areas rather than the presence of riparian habitats (Findley et al. 1975). Rock squirrels (*Spermophilus variegatus*) were regularly seen in cottonwood and Russian olive trees along the levee roads, but these rodents were not as common in the less fragmented areas within the bosque. Pocket gophers (*Thomomys bottae*) were found to be abundant in areas of mixed cottonwood and coyote willow stands with loose, sandy soils. Desert cottontails (*Sylvilagus auduboni*) were found throughout the riparian corridor in habitats ranging from cottonwood stands to grassy and herbaceous areas. Though not encountered during the Hink and Ohmart study, mule deer (*Odocoileus hemionus*) have been recorded throughout the Rio Grande Valley, particularly in the White Rock Canyon area.

Domestic and feral dogs (*Canis familiaris*) and cats (*Felis domesticus*) were the most common large mammals found in Hink and Ohmart's study area. The abundance of dog and cat tracks in the area made it difficult to assess the presence of coyotes (*Canis latrans*), gray foxes (*Urocyon cinereoargenteus*), and bobcats (*Felis rufus*), all of which have very similar tracks to their domestic counterparts. However, coyotes, foxes, and to a lesser extent, bobcats, are frequently seen and heard along the Rio Grande.

Domestic livestock were also quite common in various riparian habitats, particularly on private and Pueblo lands.

2.5.8.3 Faunal Use of Non-native Vegetation

Hink and Ohmart's 1984 study of which structural types support the greatest abundance and diversity of fauna have been verfied by later surveys (e.g. Thompson et al. 1994; Leal et al. 1996). It should be noted that these studies most specifically address structural associations. For instance, birds and some mammals are more abundant in mature forests with a varied understory because this structural type provides greater diversity of denning, nesting, and burrowing sites as well as increased forage and protection from predation. Faunal abundance does not necessarily decrease just because the vegetation happens to be non-native.

Russian olive is perhaps the best example of the impact exotics have had on area fauna. Many species of birds and mammals rely on the fruit of Russian olive as a desirable mast crop. This is particularly true of insectivores such as robins and northern flickers during seasons when arthropods have gone to ground and are no longer available. Beyond forage, Russian olive provides an excellent nesting substrate. The structure is more solid than some native canopy species, and the thorns provide a built-in protection against nest predators like the American raccoon and large raptors. Russian olive has altered New Mexico's avifauna more than any other exotic plant; it has literally rearranged the zonal distribution of some species.

Siberian elm provides nesting sites for passeriformes such as black-headed grosbeak and orioles, as well as sparrows and finches. It provides good roosting sites for animals including the porcupine, crow, and raptor species—particularly when native deciduous trees are in limited supply.

Salt cedar is sometimes categorized as the bane of native riparian ecosystems. A dense stand of salt cedar is a highly desirable nesting site for mourning doves. Mature salt cedars of taller stature provide roosting for Strigiformes, particularly Great-horned owls, barn owls, and the long-eared owl. Salt cedar also is highly attractive to many flying insects, which in turn produces great feeding for warblers, vireos, and a variety of small insectivores.

Though salt cedar has no correlate native species in New Mexico, both Russian olive and Siberian elm do have similar species. Our wildlife probably began adapting to their presence shortly after the arrival of exotic species in the early 1800s. Any consideration of impacts on riparian fauna should therefore include an understanding of their selective use of these non-native plant species.

2.5.8.4 Examples of Faunal Diversity in the Project Area

Northern Section

The floodplain in Reach 1 supports scattered stands of willow (*Salix exigua, Salix amygdaloides*), narrowleaf cottonwood (*Populus angustifolia*), and oxbow wetlands. The riparian stands within Alamosa NWR are dense enough to support a breeding population of endangered willow flycatchers (*Empidonax trailii*).

The Conejos River (Reach 2), from the confluence of the Rio Grande to Platoro Reservoir, supports an extensive area of mixed-age woody vegetation for approximately 68 river miles. The upper canopy is narrowleaf cottonwood and various species of montane willows (*Salix* sp.). There is also a breeding population of willow flycatchers in willow stands along the lower Conejos River.

The cliffs of the Rio Grande Gorge (Reach 3) are important nesting habitat for raptors, especially for golden eagles, and serve as key roosting and hibernation sites for several bat species. BLM has determined that 21 riverine miles of the Gorge are suitable for river otter introduction, although there are no known otter populations in the area (BLM 1988).

The more extensive riparian vegetation downstream of the Gorge is habitat for breeding birds including neotropical migrant songbirds and some waterfowl. In some of the larger willow stands near Velarde and on the San Juan Pueblo, southwestern willow flycatcher territories have been found. During the last three years, the willow flycatchers have apparently abandoned the Velarde sites, probably due to low nesting success (RIP-58 Moore and Ahlers 2004). There is a colony of Lewis' woodpeckers breeding in the mature cottonwoods in the reach between Alcalde Diversion Dam and the San Juan Pueblo. There is a small herd of Rocky Mountain elk (*Cerves elaphus*) in Reach 3.

Rio Chama Section

Portions of the Rio Chama exhibit the most rugged montane habitat found within the Project Area. Deer and elk are abundant along the river bottom, pinon-covered ridges, and canyon rims along some sections. Other large mammals include cougars, black bears, elk, mule deer, badgers, bobcats, coyotes, beavers, and raccoons. The walls of Chama River Canyon rise to over 1,500 feet and hosts 70 to 80 different bird varieties, including raptors such as bald and golden eagles and hawks, falcons, and owls which perch along the canyon walls and surrounding trees. The river supports species such as ducks, dippers, spotted sandpipers, and Canada geese, as well as brown and rainbow trout, flathead chub, flathead minnows, white suckers, carp, channel catfish, black crappie, and longnose dace. Adjacent mountain valleys and canyons are suitable habitat for various species of rattlesnakes and copperheads.

Central Rio Grande Section

As one of the five major North American flyways, the Rio Grande supports diversity of migratory birds. Riparian habitats within the Central Section are enhanced by several distinct wetland areas. These include Madrone Pond, the Candelaria wetland at Rio Grande Nature Center State Park, and the San Antonio Oxbow in Albuquerque, as well as the roughly 400-acre Isleta Marsh. Wetland areas are prime habitat for many amphibian species, while associated saltgrass meadows are critical for species such as the meadow jumping mouse.

San Acacia Section

Reach 14 habitats dominated by cottonwood and willow supports high diversity and density of birds (Ahlers and White, 1999). This area supports high densities of neotropical migrant landbirds during both migration and breeding periods. For example breeding birds include the yellow-billed cuckoo and Arizona Bell's vireo. In addition, this habitat supports high numbers of other riparian-obligate breeding bird species such as common yellowthroat, yellow-breasted chat, Bullock's oriole, and black-headed grosbeak (Ahlers and White 1999). This habitat also provides important resting and foraging habitat for birds during the spring and fall migration (Ellis 1995).

The remnant cottonwood stands on the disconnected western floodplain of the San Marcial portion of this reach support a unique association of wildlife. Raptors use the larger trees for perch and nest sites. Wild turkeys are also known to use certain stands for roosting habitat. Cavity-nesting species such as American kestrel, ladder-backed woodpecker, white-breasted nuthatch, and ash-throated flycatcher nest in the larger trees. Neotropical migrant landbirds known to breed in these stands include summer tanager and Lucy's warbler.

Salt cedar-dominated stands have some value for wildlife, but usually not as high as native stands. This is particularly true for native stands where foliage is mixed-aged and of high height- diversity. Salt cedar stands at Bosque del Apache, when adjacent to open weedy fields, were found to support relatively high numbers of wintering birds that use the salt cedar for cover (Ellis 1995).

The San Marcial Reach north of Elephant Butte Reservoir (Reach 14), because of its proximity to the Bosque del Apache National Wildlife Refuge, attracts large numbers of birds. Raitt (1980, 1981) documented more than 250 species of birds within the general area. Many of these species are associated with riparian-wetland habitats and include waterfowl, raptors and neotropical migrant songbirds.

The various terrestrial and aquatic habitats within this reach provide for a diversity of wildlife species. Elephant Butte Reservoir provides substantial habitat for waterfowl feeding and wintering, abundant fish supply and availability of loafing sites, and limited habitat for nesting and raising young -- primarily within the Low Flow Conveyance Channel outflow areas. Species known to nest in portions of the reservoir include Clark's grebe (*Aechmorphorus clarkii*), snowy egret (*Egretta thu*la), cattle egret (*Bubulcus ibis*) and black-crowned night heron (*Nycticorax nycticorax*). In addition, the riparian forests at the north end of the reservoir provide perch sites for many raptors, as do the cottonwood snags scattered along the shoreline.

A large number of bats, mostly from caves on private lands adjacent to the Elephant Butte Reservoir may occur during migration and in years of high insect populations. At least eight bat species, including pallid bat (*Antrozous pallidus*), Mexican free-tail bat (*Taddarida brassiliensis*) and Yuma myotis (*Myotis yumanensis*) are known to occur in the area. Because of the caves close proximity to the reservoirs, the wetland riparian communities nearby support high insect densities and may provide important foraging habitat. Bat species may also roost in large snags, cliffs, and abandoned buildings along the reservoir.

Southern Section

Caballo Reservoir area has been documented to contain approximately 4,300 acres of sensitive wildlife habitat (Reclamation 2002). The shoreline and littoral wetland vegetation is dependent on water availability, which can be extremely variable as water levels in the reservoirs increase and decrease.

2.6 *Threatened, Endangered, and Special Status Species*

The Upper Rio Grande project area supports wildlife species that are protected under the Endangered Species Act (ESA). These are federally listed as threatened or endangered species (**Table L-2.19**). The Project considers other species in addition to those with federally protected status, which will be discussed in this report, as well. The states of Colorado, New Mexico, and Texas recognize additional threatened or endangered species not listed under the ESA. Lastly, species of concern are determined by state and other agencies. A baseline evaluation is desirable for all listed species that may occur within those Project Area counties transected by the Rio Grande. The baseline data and descriptions may remove many species from any further consideration. This section reviews the status and biological characteristics of these species.

As shown in **Table L-2.19**, of the fourteen federally listed species protected under the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531-1544, as amended), only five have the potential to occur within the planning area. Three of these species have habitat preferences and behaviors that may be affected by changes to water operations on the Rio Grande: Rio Grande silvery minnow, southwestern willow flycatcher, and bald eagle. Candidate species are not included because they are not afforded protection under the ESA.

2.6.1 *Federally Listed Species*

As shown in **Table L-2.19,** a total of fourteen species that are protected under the Endangered Species Act (ESA) appear on county lists for the Project areas transected by the Rio Grande. These are federally listed as threatened or endangered species. Only three of these species commonly occur within the potential footprint of the proposed Project. This section reviews the status and biological characteristics of all fourteen federal species protected under the ESA, regardless of whether or not they may occur in habitat potentially affected by Project activities.

Federal candidate species are not included in **Table L-2.19** because they are not afforded protection under the ESA. Candidate species for counties within the Project area include: the Gunnison's sage-grouse (*Centrocercus minimus*) and boreal toad (*Bufo boreas boreas*) which are listed in Colorado; the yellow-billed cuckoo (*Coccyzus americanus*) which is listed in Colorado, New Mexico, and Texas; and the black-tailed prairie dog (*Cynomys ludovicianus*) which is a listed in New Mexico, though considered extirpated from the state. The Riparian Team determined that the yellow-billed cuckoo is the only candidate species that may be affected by Project activities. This candidate species is therefore included below for planning purposes.

Table L-2.19 Federal Listing of Endangered and Threatened Species and their Evaluation Status within this EIS

■ Will be further evaluated because species: 1) may receive possible effects
□ Removed from further consideration because species is: 2) may have suitable habitat but no known records of occurrence in affected Project area; 3) no suitable habitat in affected Project area; 4) an uncommon migrant with distribution outside project area – effects negligible species has been extirpated from state of listing.

SPECIES: Common Name / Scientific Name	Federal Status	EIS Evaluation Status			
		1	2	3	4
PLANTS					
Sneed pincushion cactus (*Coryphantha sneedii* var. *sneedii*)	E				
Pecos sunflower (*Helianthus paradoxus Heiser*)	T		□		
FISH					
Gila trout (*Oncorhynchus gilae*)	E		□		
Rio Grande silvery minnow (*Hybognathus amarus*)	E	■			
AMPHIBIANS and REPTILES					
Chiricahua leopard frog (*Rana chiricahuensis*)	T		□		
BIRDS					
Bald eagle (*Haliaeetus leucocephalus*)	T	■			
Brown pelican (*Pelecanus occidentalis carolinensis*)	E				□
Interior least tern (*Sterna antillarum athalassos*)	E				□
Mexican spotted owl (*Strix occidentalis lucida*)	T			□	
Northern aplomado falcon (*Falco femoralis septentrionalis*)	E			□	
Piping plover (*Charadrius melodus circumcinctus*)	T				□
Yellow-billed Cuckoo (*Coccyzus americanus*)	Canditate Only				
Southwestern willow flycatcher (*Empidonax traillii extimus*)	E	■			
MAMMALS					
Black-footed ferret (*Mustela nigripes*) ►	E			□	
Canadian lynx (*Lynx canadensis*)	T			□	

SOURCE: USFWS 2005

2.6.1.1 Federal Listed Species Potentially Affected by the Project

Rio Grande Silvery Minnow (*Hybognathus amarus*) ■ Endangered

The Rio Grande silvery minnow was formerly one of the most widespread and abundant species in the Rio Grande basin of New Mexico, Texas, and Mexico (Bestgen and Platania 1991). At the time of it's listing as endangered, the silvery minnow was restricted to the Middle Rio Grande in New Mexico, occurring only from Cochiti Dam downstream to the headwaters of Elephant Butte Reservoir, only 5% of its historic range (Platania 1991). The Rio Grande silvery minnow was listed as federally endangered under the Endangered Species Act in July 1994 (FR 1994). The species is listed by the State of New Mexico as an endangered species, Group II. The U.S. Fish and Wildlife Service (USFWS) documented that de-watering of portions of the Rio Grande below Cochiti Dam through water regulation activities, the construction of main stream dams, the introduction of non-native competitor/predator species, and the degradation of water quality as possible causes for declines in Rio Grande silvery minnow abundance (FR 1993).

The first designation of critical habitat for this species was published on July 6, 1999 (FR 1999a). and included the Rio Grande corridor from the New Mexico Highway 22 Bridge (immediately downstream from Cochiti Dam) to the railroad bridge near San Marcial, New Mexico, approximately 160 miles downstream. On February 19, 2003 (FR 2003a), the final rule designated critical habitat from the Highway 22 Bridge downstream to the utility line crossing the Rio Grande, a permanent identified landmark in Socorro County, New Mexico, a distance of approximately 170 miles (See Section 2.6.4, Proposed / Existing Critical Habitat Designations, for additional information).

The Rio Grande silvery minnow is a moderately sized, stout minnow, reaching 3.5 inches in total length, which spawns in the late spring and early summer, coinciding with high spring snowmelt flows (Sublette et al. 1990). Spawning also may be triggered by other high flow events such as spring and summer thunderstorms. This species is a pelagic spawner, producing neutrally buoyant eggs that drift downstream with the current (Platania 1993b). As development occurs during the drift, which may last as long as a week depending on temperature and flow conditions, the larvae seek quiet waters off-channel. Platania (1993b) found that eggs developed in 24 to 48 hours in a laboratory experiment. Considerable distance could be traversed by the drifting developing eggs when taking into account the possible length of the drift (Sublette et al. 1990; Bestgen and Platania 1991; FR 1993; Platania 1993b; Platania and Altenbach 1998). Maturity for this species is reached toward the end of the first year. Most individuals of this species live one year, with only a very small percentage reaching age two. It appears that the adults die after spawning (Sublette et al. 1990; Bestgen and Platania 1991; FR 1993).

This reproductive strategy, where the progeny are moved downstream, may partially explain the greater abundance of the species in the San Acacia reach (San Acacia Diversion Dam to Elephant Butte Reservoir), as revealed by numerous fish collections (Bestgen and Platania 1991; Platania 1993a). During recent surveys in 1999, over 95% of the Rio Grande silvery minnows captured occurred downstream of San Acacia Dam (Platania and Dudley 1999; Smith and Jackson 2000). In the past, the young drifted downstream, developed to maturity, and proceeded back upstream to occupy available habitat. Mainstem dams now block upstream migration, thus restricting the species' redistribution. Concurrently, a portion of the reproductive effort upstream of each dam is distributed downstream by the drift. It is believed that Rio Grande silvery minnows which move into the San Acacia reach (the majority of the population) are transported by high velocities in the narrow and deep channel into Elephant Butte Reservoir, where none survive (Reclamation 2000a).

The vast majority of the annual reproductive effort of Rio Grande silvery minnow normally occurs during May as water temperatures increase and appears to be triggered by a large-scale increase in stream discharge (and associated suspended sediments) associated with high-mountain snowmelt (Platania and Dudley 2004; Dudley et. al. 2005). During years of sufficient snowpack, flow in the Middle Rio Grande historically peaked in late spring and resulted in several months of sustained flooded habitats. However, dams and irrigation projects now moderate the magnitude, amplitude, and duration of spring discharge.

The Rio Grande is a sediment-laden river running through a steep rift valley that historically has resulted in a braided planform for the channel. The construction of several large dams on the Rio Grande has resulted in a 70–90 percent reduction of sediment in the river (Massong et al. 2002; Reclamation 2000a). The reduction of sediment supply has resulted in channel incision with conversion to a gravel-bedded, single-threaded channel (Reclamation 2000a). The change in planform is possibly one factor leading to a loss of nursery habitat (Porter and Massong 2004).

Artificially elevated discharge (e.g., a short-duration reservoir release in May) has also been shown to induce spawning by Rio Grande silvery minnow (Dudley et al. 2003, 2004). Although a large number of Rio Grande silvery minnow eggs were produced as a result of these "flow spikes", the production of propagules ultimately resulted in the recruitment of very few Rio Grande silvery minnow to either the 2002 or 2003 year-class (Dudley et al. 2003, 2004). Young-of-year (YOY) individuals rapidly declined in abundance following extended periods of low flows that immediately followed the flow spikes. In contrast, elevated and prolonged flows (e.g., >2,000 cfs for several weeks) during spring were significantly positively correlated ($p<0.001$) and extended low flows (e.g., <100 cfs or several months) were significantly negatively correlated ($p<0.001$) with 1993-2004 autumnal Rio Grande silvery minnow catch rates (Dudley et al. 2004, 2005). These results suggest that inundated habitats and overbank flooding produced by prolonged and elevated flows that historically occurred as a result of spring runoff are likely quite important for the successful recruitment of larval Rio Grande silvery minnow.

These conclusions are further supported by work conducted by the U.S. Bureau of Reclamation on the nursery habitats of Rio Grande silvery minnow (Porter and Massong 2004). Based on those studies, the conservation water used to initiate spawning in 2002-2003 appears to have been below the threshold for successful recruitment. The continuing decline in RGSM populations in 2002-2003 with below average spring hydrographs (Dudley et al. 2003, 2004), and increased recruitment during a near-normal spring hydrograph in 2004 (Dudley et al. 2005) support this hypothesis. The nursery habitat hypothesis predicts that recruitment will increase when flows exceed the threshold for inundating nursery habitat surfaces. It is likely that flows will have to exceed about 2,500 cfs at the Albuquerque gauge and about 2,000 cfs at the San Acacia gauge to create significant nursery habitat.

Early life history studies on Rio Grande silvery minnow indicate that individuals reared at 20-25º C (this temperature range is comparable to river temperatures during May) require about two weeks to reach a development stage where they were capable of exogenous feeding and where their mobility was notably improved (Platania 2000). This developmental stage was accompanied by changes in body shape and locomotion potentially making the larvae more able to move about more freely within or out of nursery habitats. However, growth was relatively slow and constant until about one month post-spawning after which time larvae nearly doubled in size in less than one week at 20-25º C. Ensuring that larvae have an adequate amount of time to reach critical developmental stages in inundated habitats has been demonstrated for other fishes with drifting early life stages (e.g., Coutant 2004) and is likely the case for Rio Grande silvery minnow.

Natural habitat for the Rio Grande silvery minnow includes stream margins, side channels, and off-channel pools where water velocities are lower than in the main channel. Areas with detritus and algal-covered substrates are preferred. The lee sides of islands and debris piles often serve as good habitat. Stream reaches dominated by straight, narrow, incised channels with rapid flows would not typically be occupied by the Rio Grande silvery minnow (Sublette et al. 1990; Bestgen and Platania 1991).

In the proposed project area, past actions have reduced the total habitat from historic conditions and altered habitat conditions for the Rio Grande silvery minnow. Narrowing and deepening of the channel, lack of side channels and off-channel pools, and changes in natural flow regimes have all adversely affected the Rio Grande silvery minnow and its habitat. These environmental changes have degraded spawning, nursery, feeding, resting, and refugia areas required for species survival and recovery (FR 1993). Cochiti Dam acts as a fish migration barrier. Recent fish collections and habitat surveys have demonstrated that habitat below Cochiti Dam to the northern boundary of Santa Domingo Pueblo is poor for the silvery minnow (PEC 2001). The coarser substrate, deeper channel, and higher velocities that occur in the incised channel in this reach of the Rio Grande do not provide the conditions where greater numbers of Rio Grande silvery minnows are known to occur.

Southwestern Willow Flycatcher *(Empidonax traillii extimus)* ■ Endangered

The southwestern willow flycatcher was listed as endangered under the ESA on February 27, 1995 (FR 1995b). (See Section 2.6.4, Proposed / Existing Critical Habitat Designations, for additional information). A recovery plan for the flycatcher was finalized by the (USFWS 2002), and notice of its availability was published in the Federal Register March 5, 2003 (FR 2003b).

The southwestern willow flycatcher is one of the most important species of wildlife to occur in the streamside habitats of the Rio Grande. With its federal listing as an endangered subspecies, it is considered by biologists to be an important indicator of the overall ecological health of southwestern riparian ecosystems. As such, it is accorded the highest level of protection and recovery efforts under the Endangered Species Act (ESA), and it attracts considerable public attention as a focal species for entities concerned with the broad issues of ecological conservation.

The willow flycatcher is a late spring/summer breeder that nests in late May through July and fledges young from late June to early August. Birds may be present in breeding territories from early May to late August. The willow flycatcher breeds exclusively in dense riparian habitat adjacent to rivers, streams, and wetlands. Along the Middle Rio Grande, most breeding territories have been found in young and mid-aged riparian vegetation dominated by dense growths of willow at least 10 feet high and often with some cottonwoods and other riparian woody species (Ahlers et al. 2002).

Within these willow patches, nests have been found in individual salt cedar trees, especially in older, taller willow patches where an understory of salt cedar provides suitable nesting substrate. Here, the vertical structure of more slender stems and twigs on younger plants in the understory vegetation is best suited for nest placement. Recently, breeding willow flycatchers have been found nesting in salt cedar-dominated patches on the Sevilleta NWR.

A critical factor for nesting is the presence of water, usually from overbank flooding. Along the Rio Grande, nests have been consistently found within 150 feet of surface water, typically river channels, sloughs, backwaters, and beaver ponds. Breeding southwestern willow flycatchers exhibit a strong affinity for surface water and moist soils maintained by spring flooding and high groundwater levels. And, overbank flooding is essential to maintain and create the preferred willow riparian habitat.

Willow flycatchers (and many other species of neotropical migrant landbirds) use the Rio Grande riparian corridor as stop-over habitat during migration. Studies have shown that during the spring and fall migration, willow flycatchers are more commonly found in willow habitats than in other riparian vegetation types, including the narrow band of coyote willows that line the LFC Channel in the Socorro and Bosque Reaches (Yong and Finch 1997). Recent presence/absence surveys during May have detected migrating willow flycatchers throughout the study area in vegetation types that would be considered less than suitable for breeding habitat (Moore and Ahlers 2004; Moore and Ahlers 2003).

Available suitable riparian habitat and overall numbers of willow flycatchers have apparently declined on the Rio Grande during the past century. Factors that are thought to contribute to this loss and are currently threatening the willow flycatcher are complex and inter-related (USFWS 2002). These factors include loss and degradation of breeding habitat due to changes in river flows, diversions, groundwater pumping, channelization, reduction of willow-dominated riparian vegetation, introduction of exotic riparian vegetation, fire, livestock grazing, agricultural development, urbanization, nest predation, and brood parasitism by brown-headed cowbirds. Habitat loss and degradation has also occurred on the winter range in Central and South America (USFWS 2002).

Presence absence surveys and nest monitoring for Southwestern willow flycatchers have been conducted along the middle Rio Grande since 1994 (Moore and Ahlers 2004; Moore and Ahlers 2003; Ahlers et al. 2002; Ahlers et al. 2001; Ahlers and White 2000; Ahlers and White 1999; Ahlers and White 1998; Ahlers and White 1997; Ahlers and White 1995; Johnson et al. 1996; Mehlman et al., 1995; Mehlhop and Tonne, 1994) Active territories of Southwestern willow flycatchers are found in several locations in the project area, as shown in **Table L-2.10**. Over 217 active territories were identified during intensive surveys in 2002, 2003, and 2004 (Moore and Ahlers 2004; Moore and Ahlers 2003; Kelly Stone, personnel communication 2003). Recent population expansion has occurred in the delta of Elephant Butte Reservoir as riparian vegetation has developed above the declining reservoir pool.

The southwestern willow flycatcher recovery plan (USFWS 2002) has set minimum numbers of 250 territories for the Rio Grande Recovery unit needed to warrant reclassification from Endangered to Threatened. These territories have to be distributed throughout the entire Rio Grande watershed in Colorado and New Mexico and include 50 territories in Colorado's San Luis Valley; 75 territories upstream of Albuquerque in the "Upper Rio Grande"; 100 territories from Albuquerque to Elephant Butte Dam; and 25 territories from Elephant Butte Dam to El Paso (**Table L-2.11**).

Territories usually occur in clusters along the riparian corridor within approximately 10 miles of each other. Flycatchers return to these "sites" with great fidelity to establish territories and nests year after year. The size of each territory averages approximately 1.1 hectares (2.71 acres) (USFWS 2002, p. 85) and surface water hydrology has a strong influence on nest location. During nest monitoring studies in the San Acacia Section from 1999-2003, 97% of nests were located within 164 feet (50m) of surface water when the site was first occupied, with an average distance to surface water of 78.4 feet at active nests (Darrell Ahlers, personal communication 2004).

In order to assess progress being made toward recovery of the species relative to national and regional goals, examination of the abundance of SWFL in comparison to Recovery Goals is instructive. The southwestern willow flycatcher Recovery Plan (USFWS 2002) has set a minimum goal of 250 territories for the Rio Grande Recovery Unit needed to warrant reclassification of this sub-species from Endangered to Threatened. The Recovery Management Units provide geographic distribution of the goals throughout the Rio Grande Basin. Only the Central and San Acacia Sections (Middle Rio Grande Recovery Management Unit) have achieved the goals to date. The Rio Chama, and Southern Sections of the Project Area are the farthest from reaching Recovery goals, as shown in **Table L-2.10**, although frequency and extent of flycatcher survey data varies by Section. The Recovery Plan also recommends a minimum habitat restoration target of at least twice the average territory size (2.2 hectares or 5.43 acres) per recovery goal territory (USFWS 2002, p. 85).

Vegetation was quantified at Southwestern willow flycatcher nest sites and territories on the Rio Grande based on the 2002-2003 vegetation survey. This analysis shows that the species forms territories and locates nests predominantly in Hink and Ohmart types 3 and 4 vegetation structure, less frequently in Type 5, and infrequently in Type 1 vegetation. No nests were found in Type 2 vegetation. Both native and non-native overstory vegetation were used by flycatchers, but native overstory with dense native understory vegetation was the predominant vegetation at nest locations, accounting for 77.6% of all nest locations and territories (*n=432*). Another study (Moore and Ahlers, 2004) shows that there is a definite preference willow dominated habitats. The structural composition and stem/twig density required by SWFL is developed and sustained by high frequency and duration of flooding. Breeding southwestern willow flycatchers exhibit a strong affinity for moist soils maintained by spring flooding and high groundwater levels in the overbank areas as well as for nearby availability of open water.

Table L-2.10 Known Abundance and Distribution of Southwestern Willow Flycatcher Territories along the Rio Grande

Rio Grande Section	River Reaches with Known Territories	Most Recently Known Number of Active Territories
Northern Section	1,2, 3	40-65*
Middle Rio Grande Section	13	22**
San Acacia Section	14	149**
Southern Section	16	6*

*2002 survey data; ** 2004 survey data

Table L-2.11 Known Abundance and Distribution of Southwestern Willow Flycatcher Territories along the Rio Grande in 2002-2004 as Compared to Number of Territories Desired in Recovery Plan

Project River Section	Rio Grande SWFL Recovery Management Unit	River Reaches with Known Territories	Known Active SWFL Territories	Recovery Goal Territories	Minimum Recommended Acres Suitable SWFL Habitat	2002-2004 Acres of Suitable SWFL Habitat [1] (% recommended)	Progress Toward Recovery Goal Achievement
Northern Section (Reaches 1,2)	San Luis Valley Unit	1 and 2	40-65*	50	271	Not mapped	Numeric goal met; habitat availability unknown
Northern Section (Reaches 3,4,8,9)	Upper Rio Grande Unit	4	12**		407	172 Reach 4 only	Numeric goals not met; habitat may be adequate, additional mapping needed
Rio Chama Section		8	1	75		137 Reach 7 only (76% from limited survey data)	
Central section	Middle Rio Grande Unit	13	10**		543	942	Numeric goals met; habitat abundant
San Acacia Section		14	149**	100		1,374 (426%)	
Southern Section	Lower Rio Grande Unit	16	6*	25	136	Not mapped	Numeric goals not met; habitat availability unknown
TOTALS:		7	218-243	250	136	5,163 (380%)	

[1] All suitable habitat within 50 meters of open water and within 10 miles of occupied sites.
*2002 survey data; ** 2004 survey data; Dale Stahlecker personal communication 2004

One territory is known from the Rio Grande in the Rio Chama Section (Section 8). (Dale Stahlecker, personal communication 2004). This study only surveyed Reach 7 for riparian vegetation. This area contains 2,626 acres of mapped vegetation, of which 333 acres is suitable habitat for Southwestern willow flycatcher based on vegetation composition, structure, and proximity to surface water. Only 137 acres, or 5% of the total surveyed vegetation, is located within 10 miles of the nearest active flycatcher territory on the Rio Grande, providing habitat immediately available for future colonization for up to 25 flycatcher territories in Reach 7, according to the Recovery Plan. Additional suitable habitat may be available in the unmapped Reaches 5 and 6 of the Rio Chama.

The Central Section contains 21 known active territories, primarily in Reach 13. The Central Section has 17,498 acres of riparian vegetation mapped during this study. Of that amount, 942 acres of highly suitable flycatcher habitat (5% of the total mapped vegetation) lies within 10 miles of occupied territories. This would provide colonization habitat for as many as 173 future flycatcher territories, according to the Recovery Plan. An additional 1,468 acres is suitable but occurs more than 10 miles from existing territories.

Known flycatcher territories in the San Acacia Section are concentrated in Sevilleta NWR and areas south of the Bosque del Apache NWR. An expanding population and the majority of nests are located within the upper portion of Elephant Butte Reservoir flood pool since it has been receding over the past five years. In 2004, about half of all nests known from the Rio Grande were located in the Elephant Butte flood pool. A total of 19,576 acres of riparian vegetation was mapped in this Section. Of this, 1,374 acres of highly suitable habitat exists within 10 miles of occupied territories, not considering habitat within the reservoir pool area. This represents 7% of the total mapped vegetation of the San Acacia Section, offering habitat for future colonization of as many as 253 territories. An additional 874 acres of otherwise suitable habitat occurs more than 10 miles from occupied territories.

The action area of the Upper Rio Grande contains an important portion of active southwestern willow flycatcher territories. Long-term continuation of beneficial streamflow and/or overbank flooding along the Middle Rio Grande along with establishment and maintenance of suitable vegetation are considered essential to increasing the extent of potential flycatcher habitat and overall nesting success for the species.

Bald Eagle (*Haliaeetus leucocephalus*) ■ Threatened

The bald eagle was listed as endangered throughout the conterminous 48 States under the Endangered Species Act of 1966 on July 12, 1976 (FR 1976). Since that time, the bald eagle population has clearly increased in numbers and expanded in range, as a direct result of banning DDT and other organochlorines, habitat protection, and from other recovery efforts. The species has been doubling its breeding population every 6-7 years since the late 1970s. At present, and in the foreseeable future, the major threats are destruction and degradation of its habitat and environmental contamination. Other threats include poisoning and illegal shooting, lead poisoning, and electrocution. Despite these various threats, none are of sufficient magnitude, individually or collectively, to place the species at risk of extinction. For these reasons, the population was reclassified to “threatened” on July 12, 1995 (FR 1995a). By 1999, the Service proposed that the bald eagle had undergone a sufficient enough recovery to propose that it be removed entirely from the list of threatened and endangered species (FR 1999b). The 1999 Proposed Rule still stands: If the bald eagle were de-listed, all protections under the Endangered Species Act would be removed. However, Section 4(g)(1) of the Act requires that all monitoring be continued for at least 5 years.

Although the status of the birds in the southwest recovery region is on an upward trend, the population remains small and under threat from a variety of factors, largely due to the proximity of bald eagle breeding areas to major human population centers.

The bald eagle is 3 feet long and has a 7 foot wingspan. Adults have a white head, neck and tail and a large yellow beak. Their body color is dark brownish-black. While soaring, wings are kept flat. Feet are bare of feathers. Immature bald eagles are mostly dark or mottled without the characteristic white head and tail and may be confused with golden eagles. Bald eagles require large trees or cliffs near water with abundant fish for nesting. The typical nest is constructed of large sticks, with softer materials such as leaves, grass, and moss used as nest lining. Nest are often used for many years and can grow to 6 feet in width and weigh over 220 pounds. Eagles often have one or more alternative nests within their territories. Peak egg-laying occurs in December, with hatching primarily in January. The female lays a clutch of 1 to 3 eggs. A second clutch may be laid if the first is lost. Incubation begins when the first egg is laid and usually lasts 34 to 36 days. The young generally fledge (fly from the nest) in 11 to 12 weeks, but the adults continue to feed them for another 4 to 6 weeks while they learn to hunt. Bald eagles reach sexual maturity at 4 to 6 years of age. Pairs mate for life and can live for 30 years.

Bald eagles are opportunistic feeders but prey mostly on fish and waterfowl. Bald eagles are associated with riparian and lacustrine ecosystems where major prey consists of fish and waterfowl. Snags adjacent to open water are an important habitat component that eagles use for hunting perches and night roosts. The species requires wetland and aquatic ecosystems for foraging and large trees and cliffs near water for roosting. Although some breeding occurs in New Mexico, the main threats to wintering eagle populations are habitat loss or degradation, including declines in prey and availability of roost sites.

Suitable habitat for bald eagles includes those areas with an adequate food base, perching areas, and nesting sites. In winter, bald eagles often congregate at specific wintering sites that are generally close to open water and that offer good perch trees and night roosts. In New Mexico habitat is found in the riparian zones along the Rio Grande, Pecos, Chama, Gila, San Juan, and Canadian rivers. Key habitat areas in New Mexico include winter roosts and concentration area, such as Navajo Lake, the Chama Valley, Cochiti Lake, northeastern lakes near Las Vegas and Raton, the Lower Canadian River, Sumner Lake, Elephant Butte Lake, and the upper Gila Basin. Other key habitat areas include winter roosts and concentration area, such as Navajo Lake, the Chama Valley, Cochiti Lake, northeastern lakes near Las Vegas and Raton, Sumner Lake, and Elephant Butte Lake.

The main threats to New Mexico's wintering population are habitat loss and degradation, including declines in prey and availability of roost-sites. Human disturbance near foraging areas probably poses the greatest threat to wintering eagles since birds will choose to move to more secluded areas with possibly less prey. The greatest challenge in the future will be to prevent further habitat destruction. Monitoring of nesting success is also particularly important in detecting any problems associated with contaminants in the environment. In addition, appropriate management of nesting, feeding, loafing, and wintering habitat must be a priority if we are to maintain the current upward trend in the population.

The Recovery Plan for the southwestern population was approved in 1982, and distribution is tracked (**Table L-2.12**). Captive breeding was pursued throughout the United States in the 1970s and 1980s. The eagle is protected by the State of New Mexico, where it is listed as Threatened.

Table L-2.12 Summary of January Bald Eagle Morning Distribution Surveys Rio Grande From San Marcial To Caballo Dam (Reclamation 2004)

River Reach	1/23/97	1/27/98	1/27/99	1/9-10/01	2/1/02	1/16/03	1/28/04
San Marcial (active floodplain)	2 (2/0)	0	0	1 (1/0)	0	0	0
San Marcial (west side groundwater wetlands)	1 (1/0)	1 (1/0)	0	2 (2/0)	0	2(2/0)	1(1/0)
Elephant Butte Reservoir (east side) north of Dryland Road	0	4 (2/2)	6(3/3)	0	0	0	0
Elephant Butte Reservoir (west side) wetlands north of Dryland Road	1 (0/1)	5 (3/2)	3(2/1)	1 (1/0)	2(2/0)	0	0

River Reach	1/23/97	1/27/98	1/27/99	1/9-10/01	2/1/02	1/16/03	1/28/04
Elephant Butte Reservoir (east side) Dryland Road to Nogal Canyon	9 (6/3)	4 (2/2)	8(5/0) *3(3/0)**	4 (1/3)	5(2/3)	1(1/0)	0
Elephant Butte Reservoir (west side) Dryland Road to Nogal Canyon	12 (8/4) *45 (30/15)**	17 (9/8)	18(11/7) *28(16/12)**	12 (7/5)	8(6/2)	8(2/6)	2(2/0)
Elephant Butte Reservoir (east side) Nogal Canyon to Narrows	6 (1/5)	0	2(1/1) *12(6/6)**	13 (8/5)	11(8/3)	6(4/2)	0
Elephant Butte Reservoir (west side) Nogal Canyon to Narrows	5 (3/2)	9 (6/3)	3(2/1)	8 (4/4)	7(5/2)	14(9/5)	3(2/1)
SUBTOTAL	32 (24/15)	42 (24/18)	43 (26/17)	41 (24/17)	33 (23/10)	31 (18/13)	6 (5/1)
Elephant Butte Reservoir (east side) Narrows to Dam	NS	NS	5(3/2) *3(3/0)**	16 (10/6)	25 (14/11)	15 (12/3)	18 (13/5)
Elephant Butte Reservoir (west side) Narrows to Dam	NS	NS	9 8/1)	12 (7/5)	12 (9/3)	15 (11/4)	7 (6/1)
ELEPHANT BUTTE RESERVOIR TOTAL	-	-	54 (35/19)	69 (41/28)	70 (46/24)	61 41/20)	31 (24/7)
Rio Grande EB Dam to Caballo Delta	NS	NS	1(1/0) *1(1/0)**	1 (1/0)	0	0	1 (1/0)
Caballo Reservoir (east side)	NS	NS	5(3/2) *6(3/3)**	16 (9/7)**	7(4/3)	3(3/0)	4(4/0)
Caballo Reservoir (west side)	NS	NS	5(1/4) 2(2/0)*	8 (5/3)	1(1/0)	2(2/0)	0
CABALLO RESERVOIR TOTAL	-	-	10(4/6)	25 (15/10)	8(5/3)	5(5/0)	5(5/0)
GRAND TOTAL			68 (42/26)	94 (56/38)	78 (51/27)	66 46/20)	36 (29/7)

Numbers in parentheses (# adults/#immatures - w/o white heads)
* observed during evening roost surveys
** includes eagles on east side of Rio Grande within Caballo Reservoir delta =4 adults/1 immatures

2.6.1.2 Federal Listed Species Unlikely to be Affected by the Project

Sneed pincushion cactus *(Coryphantha sneedii* var. *sneedii)* ■ Endangered

This species only occurs in El Paso County, Texas and in two counties in New Mexico. This cactus is covered with numerous needle-like spines and forms tight clumps with many branches, and may be round, cylindrical, or club shaped. At this time, the two greatest known threats to the Sneed pincushion cactus are collection by commercial and private collectors and habitat modification or destruction. It occurs in cracks of vertical cliffs or ledges of limestone mountains along with various cacti, creosote bush, ocotillo, lechuguilla, and beargrass at elevations between 3,900 to 7,000 feet. The sneed pincushion cactus does not occur in riparian zones and therefore will not be impacted by proposed activities

Pecos Sunflower (*Helianthus paradoxus Heiser*) ■ Threatened

The sunflower grows 1–2 m tall and prefers saturated saline soils associated with desert springs (cienegas) or the wetlands created from modifying desert springs; 1,000-2,000 m (3,300-6,600 ft). Adult plants grow well even when inundated. Activities that destroy wetland habitat necessary for the Pecos sunflower include erosion, groundwater depletion, water diversions, filling, livestock grazing, and Tamarix invasion (NMRPTC 1999). Helianthus paradoxus is a true wetland species growing only in wetland habitats (NMRPTC 1999).

Gila Trout *(Oncorhynchus gilae)* ■ Endangered with no Critical Habitat

The Gila trout was listed as endangered on March 11, 1967 and the revised recovery plan was completed on May 1, 1992 (USFWS 1993). The Gila trout inhabits the headwaters of several streams in the Gila National Forest, New Mexico, and in Gap Creek, Prescott National Forest, Arizona. Historically, it was found in the Verde River and its tributaries in Arizona, headwater streams of the Gila and San Francisco Rivers in New Mexico. Presently, in New Mexico, it is found in the Iron, Main Diamond, South Diamond, McKenna, and Spruce Creeks of the Gila National Forest. In the Gila National Forest, it was introduced into Mcknight, Little, Trail Canyon, Big and Sheep Corral creeks (USFWS 1993).

Habitat for the Gila trout is small, high-mountain streams. It faces extinction from habitat loss, hybridization with and competition by introduced nonnative trout (mainly rainbow trout), and from overfishing (USFWS 1993). The recovery plan calls for the establishment of the species in suitable streams within its historic range. The Gila trout is found in Sierra County, but is not within the Rio Grande Project Area.

Chiricahua Leopard Frog (*Rana chiricahuensis*) ■ Threatened

The Chiricahua leopard frog occupies a wide variety of habitat types. It is found in montane riverine, marsh and lake-side habitat at higher elevations, and playas and riparian areas in grass and scrubland environments at lower elevations (NMDGF 2004b).

The known range is divisible into two segments. One extends from montane central Arizona east and south along the Mogollon Range to montane parts of western New Mexico (Catron, Grant, Sierra Counties). The other includes extreme southwestern New Mexico (Hidalgo County), the southeastern sector of Arizona, south through Sonora, Chihuahua, to northern Durango (USFWS 2004). The species does not occur in any portion of the Project Area.

Brown Pelican (*Pelecanus occidentalis)* ■ Endangered

The brown pelican, a federally and state-listed endangered species, breeds along the eastern coast of the United States as well as the Gulf Coast. In inland areas of the United States, the brown pelican occurs as a vagrant. Only 13 occurrences have been reported from New Mexico (USFWS 2004). As a rare, non-breeding visitor to portions of the project area, it is unlikely that this species will be significantly affected by the proposed actions.

Interior Least Tern (*Sterna antillarum athalassos)* ■ Endangered

The interior least tern is an endangered species that occurs as a rare transient in the Rio Grande floodplain. This species is federally and state listed as endangered. The least tern nests in open sandy areas such as the river sandbars and alkali flats along the Pecos River in southeastern New Mexico. Occasional migrant least terns have been observed at Bosque del Apache (USFWS 2004). Because least terns are rare transients and are not known to breed within the action area, no further consideration is needed.

Mexican Spotted Owl (*Strix occidentalis lucida*) ■ Threatened

The Mexican spotted owl occurs in varied habitat, consisting primarily of mature montane forest and woodland, and shady wooded canyons. In forested habitat, uneven-aged stands with a high canopy closure, high tree density, multi-layered canopy structure, and a terrain with slopes greater than 15 degrees, appear to be key habitat characteristics. The owl nests in snags, canyon-wall cavities, and abandoned raptor nests (USFWS 2004).

In New Mexico, the Mexican spotted owl has been recorded in all montane regions from the San Juan, Jemez, and Sangre de Cristo mountains in the north, to the Guadalupe and Animas mountains in the south. Records for lowland occurrences exist for: Navajo Lake, Mountainair, Lower San Francisco Valley, Estancia, Grants, Hurley, Burro Mts., Carlsbad Caverns National Park and San Andres NWR. These records probably represent dispersing individuals (USFWS 2004). As no suitable habitat exists within the Project Area, this species will not be given further consideration.

Northern Aplomado Falcon (*Falco femoralis septentrionalis*) ■ Endangered with no Critical Habitat

Habitat for the northern aplomado falcon includes open terrain with scattered trees, relatively low ground cover, an abundance of small- to medium-sized birds, and a supply of suitable nesting platforms, particularly yuccas and mesquite. Habitat degradation due to brush encroachment, overcollecting, and reproductive failure caused by organochlorine pesticides have led to the species decline (USFWS 2004).

Historically, the bird’s range included the United States, southeastern Arizona, southern New Mexico, and southern Texas. Presently, no nests have been verified in the United States since 1952, when a nest was reported from near Deming, New Mexico (USFWS 2004). A few migrant birds have been reported in New Mexico, but there are no known records for sightings within the Project Area.

Piping Plover (*Charadrius melodus circumcinctus*) ■ Threatened

The piping plover occurs on sandflats or along bare shorelines of rivers, lakes, or coasts. The piping plover forages on a variety of invertebrates, including marine worms, fly larvae, beetles, crustaceans, mollusks, and other small animals and their eggs. During the winter, piping plovers use algal, mud, and sand flats along the Gulf Coast (NMDGF 2004c).

Considered common in the 1930's, the piping plover vanished as a nesting species from many areas. In 1993, the North American population was estimated at 5,000. Piping plovers have been reported from New Mexico on only seven occasions, most recently on April 2001. In New Mexico, this bird is a rare spring migrant that has been reported at Bosque del Apache National Wildlife Refuge (NMDGF 2004c).

Yellow-billed Cuckoo (*Coccyzus americanus*) ■ Candidate

The western population of the yellow-billed cuckoo experienced a severe decline in distribution and abundance throughout the western United States. This is a federally listed candidate species; candidate species have no formal protection under the ESA. However, the yellow-billed cuckoo is considered in this document for planning purposes as it may be affected by Project activities. This species prefers riparian habitat with dense willow, cottonwood, saltcedar and/or mesquite. Suitable breeding habitat consists of large stands of dense willow and cottonwood, but non-natives like saltcedar are also used (FR 2001). Nesting territories in some portions of the Rio Grande are located in dense or narrow saltcedar stands or mixed saltcedar/willow habitat.

Black-footed Ferret (*Mustela nigripes*) ■ Endangered with no Critical Habitat

The black-footed ferret is a rare mammal found in grassland plains and surrounding mountain basins to 10,500 feet in elevation. This ferret is usually found in association with prairie dogs, which are the primary food source and also provide the ferrets with abandoned burrows. A major impact has been loss of habitat due to destruction of original grasslands as well as prairie dog control programs that have eliminated the ferret's main food source and shelter. Canine distemper may also have been a factor in their decline (USFWS 2004).

Historically, the mammal's range included all or portions of the States of Colorado, Arizona, Utah, New Mexico, Kansas, Montana, Nebraska, Oklahoma, Texas, Wyoming, North Dakota, South Dakota, and the Provinces of Alberta and Saskatchewan, Canada. Presently, New Mexico has had no verified sighting since around 1960. It may still exist in McKinley, Rio Arriba, and San Juan Counties, New Mexico. The best possibility in New Mexico appears to be in this "four-corners" area (USFWS 2004).

Canadian Lynx *(Lynx canadensis)* ■ Threatened

The Canadian lynx is listed as threatened in three Colorado counties within the Project Area: Alamosa, Conejos, and Costilla; and two New Mexico counties: Rio Arriba and Taos. In the west, lynx live in subalpine/coniferous forests. Mature forests with downed logs and windfalls provide cover for denning, escape and protection from severe weather. The same areas provide habitat for the lynx's primary prey, the snowshoe hare, and other small mammals and birds that supplement their diet (NMDGF 2004d).

According to Frey (2004) there are no historic specimens available of this species in New Mexico, although its range undoubtedly included the San Juan and Sangre de Cristo Mountains based on its occurrence in contiguous habitat in these mountains in adjacent areas of Colorado.

2.6.2 *State Listed Species*

Wildlife species listed at the state level do not carry protection under the federal Endangered Species Act. However, wildlife management practices give due consideration to state-listed species that may be impacted by a given project. As shown in **Table L-2.13**, a total of 42 species listed by state wildlife authorities are found in Project-area counties transected by the Rio Grande. Eight of these species may occur within the Project area, or rely on suitable habitat that occurs in the Project area. This section reviews the biological characteristics of these eight species.

Table L-2.13 State Listing of Threatened or Endangered Species and their Evaluation Status within this EIS

■ Will be further evaluated because species: 1) may receive possible effects
□ Removed from further consideration because species is: 2) may have suitable habitat but no known records of occurrence in affected Project area; 3) no suitable habitat in affected Project area; 4) an uncommon migrant with distribution outside project area – effects negligible ► species has been extirpated from state of listing

SPECIES: Common / Scientific Name	State Status			EIS Evaluation Status			
	CO	NM	TX	1	2	3	4
PLANTS							
Pecos sunflower (*Helianthus paradoxus Heiser*)		E			□		
FISH							
Bluntnose shiner - Rio Grande ssp. (*Notropis simus simus*) ►			T		□		
Rio Grande silvery minnow (*Hybognathus amarus*)		E		■			
AMPHIBIANS and REPTILES							

SPECIES: Common / Scientific Name	State Status			EIS Evaluation Status			
	CO	NM	TX	1	2	3	4
Chihuahuan mud turtle (*Kinosternon hirtipes murrayi*)			T		□		
Jemez Mountains salamander (*Plethodon neomexicanus*)		T			□		
Western boreal toad (*Bufo boreas boreas*)	E	E				□	
BIRDS							
American peregrine falcon (*Falco peregrinus anatum*)		T	E			□	
Baird's sparrow (*Ammodramus bairdii*)		T				□	
Bald eagle (*Haliaeetus leucocephalus*)		T		■			
Bell's vireo (*Vireo bellii*)**		T		■			
Boreal owl (*Aegolius funereus*)		T				□	
Broad-billed hummingbird (*Cyanthus latirostris magicus*)		T					□
Brown pelican (*Pelecanus occidentalis carolinensis*)		E					□
Common black-hawk (*Buteogallus anthracinus anthracinus*)		T	T	■			
Common ground dove (*Columbina passerina pallescens*)		E				□	
Costa's hummingbird (*Calypte costae*)		T					□
Gray vireo (*Vireo vicinior*)		T				□	
Interior least tern (*Sterna antillarum athalassos*)		E					□
Lucifer hummingbird (*Calothorax lucifer*)		T					□
Mexican spotted owl (*Strix occidentalis lucida*)	T		T			□	
Neotropic cormorant (*Phalacrocorax brasilianus*)		T		■			
Northern aplomado falcon (*Falco femoralis septentrionalis*)		E	E			□	
Piping plover (*Charadrius melodus circumcinctus*)		E					□
Southwestern willow flycatcher (*Empidonax traillii extimus*)	E	E	E	■			
Varied bunting (*Passerina versicolor*)		T					□
Violet-crowned hummingbird (*Amazilia violiceps ellioto*)		T					□
Western burrowing owl (*Athene cunicularia*)	T					□	
White-eared hummingbird (*Hylocharis leucotis borealis*)		T					□
White-tailed ptarmigan (*Lagopus leucurus altipetens*)		E				□	
Whooping crane (*Grus americana*)	E	E	E				□
Zone-tailed hawk (*Buteo albonotatus*)			T				□

SPECIES: Common / Scientific Name	State Status			EIS Evaluation Status			
	CO	NM	TX	1	2	3	4
MAMMALS							
American marten (*Martes americana origenes*)		T				□	
Black-footed ferret (*Mustela nigripes*) ►	E		E			□	
Botta's pocket gopher (*Thomomys bottae*)	E					□	
Canada lynx (*Lynx canadensis*)	E					□	
Desert bighorn sheep (*Ovis canadensis mexicana*)		E				□	
Gray wolf (*Canis lupus*) ►			E			□	
Meadow jumping mouse (*Zapus hudsonius luteus*)		T		■			
Organ Mountains Colorado chipmunk (*Tamias quadrivittatus australis*)		T				□	
Oscura Mountains Colorado chipmunk (*Tamias quadrivittatus oscuraensis*)		T				□	
Spotted bat (*Euderma maculatum*)		T			□		
Wolverine (*Gulo gulo*) ►	E					□	

SOURCE: USFWS 2005; NMDGF 2005

2.6.2.1 State Listed Species Potentially Affected by the Project

Rio Grande Silvery Minnow ■

See Species Account in Section 2.6.1, Federal Listed Species

Bald eagle ■

See Species Account in Section 2.6.1, Federal Listed Species

Common black-hawk (*Buteogallus anthracinus anthracinus*) ■ Threatened

The common black-hawk may occur in the Albuquerque Reach (NMDGF 2004e). Though the common black-hawk is considered rare in Bernalillo County, nesting was observed in the Isleta Reach during the summer of 2003 (Sartor Williams, personal communication 2003). The species primarily occupies riparian woodlands, particularly areas with well-developed cottonwood galleries, or a variety of woodland and marsh habitats along permanent lowland streams. Breeding black-hawks require mature riparian forest stands near permanent water. Most birds winter south of the U.S., although some records report occurrences within southern Arizona and the Gulf coast in Texas. The diet of this riparian-obligate species consists mainly of fish, insects, crayfish, amphibians, and reptiles, but occasionally they will take small mammals and birds. Loss of riparian habitat poses the greatest risk to the species. In 1996 the NMDGF estimated 60 to 80 breeding pairs in the state.

Neotropic cormorant (*Phalacrocorax brasilianus*) ■ Threatened

The neotropic cormorant typically inhabits areas in close proximity to large bodies of water, including reservoirs. The neotropic cormorant nests in vegetation, such as dead snags or trees, located adjacent to or over water. Nesting neotropic cormorants require stands of trees or shrubs in or near water and free from human disturbance (NMDGF 2004f). The species' range extends from southern New Mexico and southern Louisiana southward through Central America and portions of the Caribbean into South America. In New Mexico, the species occupies areas in the Rio Grande Valley at Elephant Butte and Caballo Reservoirs. It also commonly occurs at the Bosque del Apache National Wildlife Refuge and has been reported occasionally elsewhere in the state.

Southwestern willow flycatcher ■

See Species Account in Section 2.6.1, Federal Listed Species

Bell's vireo (*Vireo bellii*) ■ Threatened

Bell's vireo is listed as threatened by the New Mexico Game and Fish Department. Its habitat requirements appear to overlap those of the southwestern willow flycatcher, often with nests in dense, periodically flooded stands of willows and other riparian shrubs (NMDGF 2004g). Bell's vireos were detected in young and mid-age classes of riparian habitat along the Rio Grande.

New Mexican Meadow Jumping Mouse (*Zapus hudsonius luteus*) ■ Threatened

The meadow jumping mouse is a NMDGF Threatened species and is considered a Species of Concern. Because of its restricted range and documented loss of natural riparian habitat, it was believed that Z.h.luteus was approaching extinction in New Mexico; no extant populations were found along the Rio Grande Valley between 1930 and 1976. However, the distribution and status of the genus within the Southwest had not been well documented. In addition, little was known about its habitat requirements or sensitivity to habitat loss. In 1994, it was reported that, "The meadow jumping mouse is uncommon in wetland impoundments and canal banks of the Bosque del Apache National Wildlife Refuge" (NMDGF 2004h). However, in 1997 a survey stated that biologists "found meadow jumping mice in all habitats that were surveyed at Bosque del Apache National Wildlife Refuge (NMDGF 2004h. It appears the taxon persists in New Mexico in fair numbers in the areas from which it has been reported, and may be expanding territories as well.

Recently, concerns had developed that isolated populations were being threatened not only by agricultural and industrial development along major rivers but also by recreational development and range management activities in montane areas (NMDGF 2004h).

The meadow jumping mouse requires dense vegetation to persist and typically occupies marshes, moist meadows, and riparian habitats. Preferred habitat is permanent streams, moderate to high soil moisture, and dense and diverse streamside vegetation consisting of grasses, sedges, and forbs (Morrison 1985, Morrison 1988). Reports indicate that the key habitat areas for the species include wetlands in the Jemez Mountains and the central Rio Grande Valley; in Espanola, Isleta Marsh, and Bosque del Apache NWR (Morrison 1985, 1988). In the Rio Grande Valley, the meadow jumping mouse preferred the edges of permanent ditches and cattail stands (NMDGF 2004h). The species has recently been found occupying man-made habitats such as irrigation drains and canals, and many questioned if the species is threatened by habitat destruction (Morrison 1990). However, recent observations of this species by Morrison suggest it should be investigated for possible delisting when resources are available (NMDGF 2004h).

Spotted bat (*Euderma maculatum*) ■ Threatened

Widely distributed across western North America, the spotted bat has been verified in 11 localities in New Mexico, all west of the Rio Grande. The spotted bat uses a wide variety of habitats, including ponderosa pine and spruce-fir forests, pinyon-juniper woodlands, and riparian communities. Generally found in forested areas between 3,900 and 10,600 feet in elevation, they migrate through lower elevationsin all seasons outside of summer. The spotted bat utilizes cliff faces and rock crevices for roosting, and such rocky areas are essential habitat for the species (NMDGF 2004b).

2.6.2.2 State Listed Species Unlikely to be Affected by the Project

The five species below are not known to occur within the affected portions of the Project Area. However, they are discussed below because potentially suitable habitat is found in the Project Area.

Pecos Sunflower (*Helianthus paradoxus Heiser*) ■ Threatened

See species account under Section 2.6.1, Federal Listed Species

Bluntnose shiner - Rio Grande ssp. (*Notropis simus simus*) ■ Threatened

The bluntnose shiner is generally found in main river channels, particularly below obstructions. It appears to prefer sandy substrates, low-velocity laminar flows, and at depths of 17 to 41 cm. After age II, the species exhibits a strong affinity for main-channel habitats (Sublette et al. 1990). Though the subspecies *N.s. pecosensis* still survives in the Pecos River, the Rio Grande sub-species *N.s. simu*s is now extinct in New Mexico (Propst 1999). However, it remains and is listed as threatened in El Paso County, Texas, the southernmost county within the Project Area.

Chihuahuan Mud Turtle (*Kinosternon hirtipes murrayi*) ■ Threatened

The Chihuahuan mud turtle is in the Kinosternon genus, which has a wide distributional range occurring from southern Canada through much of South America (Kirpatrick 1997). This species is listed as threatened in El Paso County, Texas, the southernmost county in the Project Area through which the Rio Grande flows. The semi-aquatic Chihuahuan mud turtle, in general, prefers slow-moving or still bodies of water. Preferred locations often have soft-bodied beds, consisting of either sand or mud, and support a large amount of aquatic vegetation. The species eats invertebrates and breeds March-July (Kirkpatrick 1997). Texas Parks and Wildlife places this species near Big Bend, Texas, beyond the Project Area.

Jemez Mountains salamander (*Plethodon neomexicanus*) ■ Threatened

The Jemez Mountains salamander is endemic to north-central New Mexico, found only in the Jemez Mountains. Though rarely observed on the surface, this salamander occurs from 7,200-11,256 ft. elevation in mixed conifer habitats with abundant surface rocks and rotting logs. Logging, wildfires, mining, road construction, and disease are among the factors responsible for the declining populations of the Jemez Mountain salamander. Based on recent surveys, it appears this salamander is now extinct in some of its historic territories, and the Department of Game and Fish recommends it be upgraded to Endangered status within the State (NMDGF 2004b).

2.6.3 *Species of Concern*

Species of Concern are not federally listed and therefore have no Federal ESA status. However, the U.S. Fish and Wildlife Service (USFWS) considers Species of Concern to be those species for which further biological research and field study are needed to resolve their conservation status. There is also the possibility that they may be considered sensitive, rare, or declining on lists maintained by other Federal agencies, State wildlife agencies, Natural Heritage Programs, or professional/academic scientific societies. The USFWS includes Species of Concern for planning purposes only.

Numerous rare and specialized species occupy riparian and wetland ecosystems in the Southwest. As these ecosystems have been altered and fragmented through human uses, the species that rely on them have declined. Some species, such as the river otter, have been extirpated from the Rio Grande Valley entirely. As a result, several species within the project area of the Upper Rio Grande are protected by various federal and state regulations.

Species of concern occurring within counties in the Project area are shown in **Table L-2.14**; the states encompassing the Rio Grande Basin are Colorado, New Mexico, and Texas. To identify the most environmentally beneficial alternative, the Riparian and Aquatic Habitat Subcommittees considered the potential Project-related impacts to Species of Concern and their habitats. Some of these species may be sensitive to any future conditions that include permanent or lengthy dewatering of the river channel, increased loss or fragmentation of native riparian vegetation, or drying of riparian habitats in the floodway of the Rio Grande Basin. Species were further evaluated to determine if they are actually found within the immediate Project area. For reasons detailed below (**Table L-2.14**), an in-depth analysis was not conducted for every Species of Concern—only those along the immediate riparian zone that may potentially be affected by Project activities. The biological information for these species is found after **Table L-2.14**.

Table L-2.14 Species of Concern and their Evaluation Standing

■ 1) species may be affected by changes in water operations

□ Removed from further consideration because species is: 2) may have suitable habitat but no known records of occurrence in affected Project area; 3) no suitable habitat in affected Project area; 4) an uncommon migrant with distribution outside project area – effects negligible, ► species has been extirpated from state of listing

Species: Common / Scientific Name	State of Status			Evaluation Standing			
	CO	NM	TX	1	2	3	4
PLANTS							
Arizona willow (*Salix arizonica*)		X				□	
Bog alkaligrass (*Puccinellia parishii*)		X			□		
Gila thistle (*Cirsium gilense*)		X				□	
Mogollon Mountain ragwort (*Senecio quaerens*)		X			□	□	
Sapello Canyon larkspur (*Delphinium sapellonis*)		X			□		
Texas false saltgrass (*Allolepis texana*)			X		□		
Wright's thistle (*Cirsium wrightii*)		X			□	□	
INSECTS							
Anthony blister beetle (*Lytta mirifica*)		X				□	
Desert viceroy butterfly (*Limenitis archippus obsoleta*)		X		■			
New Mexico silverspot butterfly (*Speyeria nokomis nitocris*)		X			□		
San Ysidro tiger beetle (*Cicindela willistoni funaroi*)		X			□		
William Lar's tiger beetle (*Cicindela fulgida williamlarsi*)		X			□		
FISH							
Desert sucker (*Catostomus clarki*)		X			□		
Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*)		X			□		
Rio Grande sucker (*Catostomus plebeius*)		X			□		
Roundtail chub (*Gila robusta*)		X			□		
Sonora sucker (*Catostomus insignis*)		X			□		
White Sands pupfish (*Cyprinodon tularosa*)		X			□		

Species: Common / Scientific Name	State of Status			Evaluation Standing			
	CO	NM	TX	1	2	3	4
AMPHIBIANS AND REPTILES							
Desert kingsnake (*Lampropeltis getula splendida*)		X					□
Jemez Mountains salamander (*Plethodon neomexicanus*)		X			□		
New Mexico garter snake (*Thamnophis sirtalis dorsalis*)			X	■			
Northern leopard frog (*Rana pipiens*)	X	X	X	■			
BIRDS							
American bittern (*Botaurus lentiginosus*)		X					□
American peregrine falcon (*Falco peregrinus anatum*)		X				□	
Baird's sparrow (*Ammodramus bairdii*)		X				□	
Bell's vireo (*Vireo bellii*)		X		■			
Black tern (*Chlidonias niger surinamensis*)		X					□
Ferruginous hawk (*Buteo regalis*)	X	X				□	
(Greater) sandhill crane (*Grus canadensis tabida*)	X			■			
Gunnison sage grouse (*Centrocercus minimus*)	X					□	
Long-billed curlew (*Numenius americanus*)	X	X					□
Mountain plover (*Charadrius montanus*)		X				□	
Neotropic cormorant (*Phalacrocorax barsilianus*)		X					□
Northern goshawk (*Accipiter gentilis*)		X				□	
Western burrowing owl (*Athene cunicularia hypugaea*)		X				□	
Western snowy plover (*Charadrius alexandrinus*)	X	X					□
MAMMALS							
Allen's big-eared bat (*Idionycteris phyllotis*)		X				□	
Big free-tailed bat (*Nyctinomops macrotis*)		X	X				□
Black-tailed prairie dog (*Cynomys ludovicianus*)			X			□	
Desert pocket gopher (*Geomys bursarius arenarius*)		X				□	
Fringed myotis (*Myotis thysanodes thysanodes*)		X	X			□	
Goat Peak pika (*Ochotona princeps nigrescens*)		X			□	□	
Northern pocket gopher (*Thomomys talpoides*)	X					□	
Organ Mountains Colorado chipmunk (*Tamias quadrivittatus australis*)		X				□	
Pale Townsend's big-eared bat (*Plecotus townsendii pallescens*)		X	X			□	
Pecos River muskrat (*Ondatra zibethicus ripensis*)		X			□		
Southwestern otter (*Lutra canadensis sonorae*) ►		X			□		
Spotted bat (*Euderma maculatum*)		X					□
Townsend's big-eared bat (*Plecotus townsendii*)		X				□	
Yuma myotis (*Myotis yumanensis yumanensis*)		X	X		□		

Species: Common / Scientific Name	State of Status			Evaluation Standing			
	CO	NM	TX	1	2	3	4
Western red bat (*Lasiurus blossevillii*)		X			□		
White Sands woodrat (*Neotoma micropus leeucophaea*)		X				□	

SOURCES: USFWS 2005

2.6.3.1 Species of Concern Potentially Affected by the Project

Table L-2.14 lists 52 species of concern, not considered threatened or endangered, which may occur anywhere within counties transected by the Rio Grande. The Riparian and Aquatic Teams have determined that five of these species may occur within, or utilize, the riparian zone, and thus receive possible effects. Because no potential impacts will occur on the remaining 47 species of concern, no further discussion is necessary. This section reviews the status and biological characteristics of the five species potentially affected. Federal actions should meet or improve conditions for the species of concern described below.

The **desert viceroy butterfly** (*Limenitis archippus obsoleta*) is associated with a number of riparian habitats, especially willow (*Salix* sp.) or poplar (*Populus* sp.) forests occurring along stream corridors. The desert viceroy butterfly is a riparian obligate species because the larvae of the species rely on willows. The species historically occurred in Arizona, California, Nevada, and New Mexico, but complete and current distribution information for the butterfly is lacking. In New Mexico, the species survives in isolated populations in the Gila River, Rio Mimbres, Rio Grande and Pecos River valleys (Toliver et al. 1994).

The **New Mexico garter snake** (*Thamnophis sirtalis dorsalis*) 1993: This garter snake is common throughout refuge wetlands, farms and woodlands (NMDGF 2004i). All riparian vegetation types are important to this snake, both montane and lowland. Within the Project area it has been recorded at several places including the Bosque del Apache National Wildlife Refuge. It is extremely adaptable to many habitat types and will not be negatively impacted by any Project operations changes (Charles Painter, NMDGF personal communication 2004).

The **northern leopard frog** (*Rana pipiens*) is widespread in North America. In New Mexico, this species is found along the entire length of the Rio Grande and throughout the western half of the state (Degenhardt et al. 1996). It is mainly found in streams and rivers, but also occurs in marshes, ponds, and irrigation ditches. The northern leopard frog is found in a variety of aquatic habitats along the Rio Grande. Direct impacts to any individuals of this species are not likely to result from Project activities

Bell's vireo (*Vireo bellii*) ■ See Species account under **Section 2.6.2 State Listed Species**

The **Greater sandhill crane** (*Grus canadensis tabida*) migrates almost statewide and are thus considered uncommon to locally abundant. They are found during fall months at Sevilleta NWR and winter mainly in the middle and lower Rio Grande and lower Pecos valleys. They were documented in the Rio Grande Valley State Park, Bernallilo Co., NM (Stahlecker and Cox, 1997) and are well-known winter residents at Bosque del Apache NWR, where farm fields are maintained specifically to support wintering species. They forage in agricultural fields but also commonly forage for frogs, rodents and insects, generally returning to water for night safety (NMDGF 2004j).

2.6.4 *Proposed / Existing Critical Habitat Designations*

2.6.4.1 Rio Grande Silvery Minnow

Critical habitat for the Rio Grande silvery minnow was originally designated in July 1999 (FR 1999a) and included the Rio Grande corridor from the New Mexico Highway 22 Bridge (immediately downstream from Cochiti Dam) to the railroad bridge near San Marcial, New Mexico, approximately 160 miles downstream. Constituent elements of critical habitat required to sustain the Rio Grande silvery minnow include stream morphology that supplies sufficient flowing water to provide food and cover needs for all life stages of the species; water quality to prevent water stagnation (elevated temperatures, decreased oxygen, etc.); and water quantity to prevent formation of isolated pools that restrict fish movement, foster increased predation by birds and aquatic predators, and congregate disease-causing pathogens (FR 1999a).

In November 2000, the U.S. District Court for the District of New suspended the designation pending preparation of an Environmental Impact Statement by the USFWS and the formulation of a new rule. On February 19, 2003, the final rule designated critical habitat from the Highway 22 Bridge downstream to the utility line crossing the Rio Grande, a permanent identified landmark in Socorro County, New Mexico, a distance of approximately 170 miles. This designation became effective March 31, 2003 (FR 2003a).

2.6.4.2 Southwestern Willow Flycatcher

The southwestern willow flycatcher was listed as endangered under the ESA on February 27, 1995 (FR 1995b). Critical habitat for the SWFL was designated on July 22, 1997 (FR 1997), but at that time the Middle Rio Grande was not included. The 10th Circuit Court of Appeals set this critical habitat designation aside on May 11, 2001 (10th Circuit Court of Appeals 2001). A recovery plan for the flycatcher was finalized by the (USFWS 2002), and notice of its availability was published in the Federal Register March 5, 2003 (FR 2003b). On October 12, 2004 the Service once again published notice (FR 2004) that critical habitat was being proposed for the flycatcher. A draft Environmental Assessment and economic analysis were prepared and public input solicited. It is anticipated that a final decision to designate critical habitat will be made in the fall of 2005. Portions of the upper and middle Rio Grande are included in the proposal for critical habitat designation.

The proposed extent of critical habitat within the Project Area begins just south of the Alameda Bridge and extends southward to Elephant Butte Reservoir. The I-40 to Central and SDC subreaches fall within the proposed critical habitat area; the entire NDC subreach lies outside of the designated portion of the Rio Grande floodplain. As described in the 2003 BO, declining SWFL numbers have been attributed to loss, modification, and fragmentation of riparian breeding habitat, loss of wintering habitat, and brood parasitism by the brown-headed cowbird. Habitat loss and degradation are caused by a variety of factors, including urban, recreational, and agricultural development; water diversion and groundwater pumping; and channelization, dams, and livestock grazing.

3.0 IMPACTS TO BIOLOGICAL RESOURCES

3.1 *Planning for Ecological Benefits*

A detailed comparison of the biological performance of each alternative was made using ten biological resource categories. The Riparian and Aquatic Interdisciplinary Teams assigned each resource category an objective and relative weight to assess and rank the biological performance of each alternative. Resource criteria were then established to assess the relative performance of each alternative at meeting ecological objectives. Quantitative or qualitative measures were selected to represent the performance of the objective (**Table L-3.1**).

Data were collected, analyzed, weighted, and incorporated into a computerized decision support matrix that provided a final ranking of the alternatives compared to one another in order to first determine the most beneficial water operations for most biological resources.

The results of the analysis of relative benefits of the alternatives are reported in the Upper Rio Grande Water Operations Environmental Impact Statement. Following the evaluation of decision criteria, the alternatives were evaluated for impacts, both beneficial and adverse, compared to the No Action Alternative. The methods and results of the impacts analysis are reported here. A final ranking of the alternatives for biological benefits is provided.

Table L-3.1 Biological resources and performance measures utilized to determine biological performance of Alternatives

Biological Resource and Guiding Objective		
Criteria	**Measure**	**Relative Weight (%)**
Riverine Habitats ▪ Supports river channel habitats		21
Modeled Habitat for Indicator Species	Cubic feet	
Duration of overbank flooding	Days/year	
Area of Overbank Flooding	Acres	
Peak Flow Magnitude and Duration	cfs, days	
River Sport Fish ▪ Supports river sport fish populations		8
Modeled Habitat for Indicator Species	Cubic feet	
Duration of overbank flooding	Days/year	
Area of Overbank Flooding	Acres	
Peak Flow Magnitude and Duration	cfs, days	
Reservoir Sport Fish ▪ Supports reservoir sport fish populations		2
Net reservoir elevation rate of change (ft/week)	Feet/week	
Area of littoral habitat	Acre-days	
Reservoir Elevation Rate of Change	Acre-feet/year	
Riparian Habitats ▪ Provides vegetation structural and compositional diversity		14
Supports Regeneration of Native Vegetation	Acre-days of spring OBF	
Criteria	**Measure**	**Relative Weight (%)**

Biological Resource and Guiding Objective		
Supports H&O Vegetation Classifications Type I and II	Average annual acre-days	
Supports H&O Vegetation Classifications Type III and V	Average annual acre-days	
Supports USFWS Vegetation Community Type 2	Average annual acre-days	
Supports USFWS Vegetation Community Type 3	Average annual acre-days	
Amount of Overbank Flooding (OBF)	Mean annual max Acres OBF	
Frequency and Timing of OBF	Percent years of spring OBF	
Wetlands ▪ Maintains or improves wetlands function at existing sites		9
Maintains Minimum Groundwater Table Levels	# days <25th percentile Q of baserun	
Maintains Seasonal High Water Levels	# days >75th percentile Q of baserun	
Natural Management Areas ▪ Supports biological goals of designated natural management areas		4
Provides Overbank Flooding at Specific Locations	Mean annual acre-days flooded at specific locations	
Instream and Overbank Hydrologic Variability ▪ Provides flow variability		16
Peak Flow Variability	Peak flow coefficient of variation	
Adaptive Flexibility ▪ Conservation storage and other flexibilities		3
Ability to Offset Drought on Low-flow Days	Potential days >100 cfs supplemental water	
Aquatic and Riparian Fauna ▪ Supports fish and wildlife diversity		16
Supports H&O Type I	Total acre-days inundation	
Supports H&O Type II	Total acre-days inundation	
Supports H&O Type III	Total acre-days inundation	
Supports H&O Type IV	Total acre-days inundation	
Supports H&O Type V	Total acre-days inundation	
Supports H&O Type VI	Total acre-days inundation	
Threatened & Endangered Species ▪ Maintains or improves T&E [species] habitat		7
Increases Riparian Inundation	Mean annual acre-days of inundation	
Supports Existing SWFL Habitat	Maximum days OBF in existing territories	
Supports Existing Bald Eagle Habitat	Reservoir elevation and fisheries habitat	
Supports NM Meadow Jumping Mouse Habitat	Average annual acre-days of wet meadow inundation	
Supports Yellow-billed Cuckoo Habitat	Average annual acre-days H &O Type III and V inundation	

3.2 Aquatic Resources

3.2.1 Riverine Habitat Criteria Evaluation Methods

As described in the Aquatic Habitat and Hydraulic Modeling Study for the Upper Rio Grande Water Operations Model (Bohannon-Huston et al 2004), habitat suitability for fish species was determined by reanalyzing information and data collected in studies conducted on the Rio Grande (Dudley and Platania, 1997), and the Platte River in Nebraska and the South Platte River in Colorado (Peters, et al 1989).

The eight sites identified for study of impacts to riverine resources (shown in Chapter 2, Figure L-2.1), were sampled and calibrated with the URGWOM model. The critical flows for each sampling site included the 50% (medium flow) and 90% (low flow) occurrence of mean daily discharge, as indicated at the nearest gage to the site, at which geo-referenced x, y, and z data and velocity data within the river channel were collected. Field sampling was dependant on rainfall and runoff conditions. Staff gages were established (at a minimum) at the upper and lower extent of all study sites to enable collecting stage-level data for the 10% (high flow) occurrence level of mean daily discharge. This data would interface with high and medium flow data to develop the two-dimensional habitat model.

Due to drought conditions present in the study area during the sampling period (February 1 and 2, 2002), high-flow calibration data could not be collected. Since the emphasis in the habitat modeling is primarily on the lower flows, the absence of high-flow calibration data is not considered to be a significant limitation in the model results (Personal communication Robert Mussetter, MEI Inc.).

A GIS model was developed for habitat quantification (MEC 2003a). The model uses the analytical tools in ArcView 3.2a or 8.1 to combine the habitat-use information with the habitat data that is generated from the two-dimensional hydraulic model. ArcView scripts developed in the modeling effort area are also compatible with ArcView 3.2a or 8.1 (based on Visual Basic, rather than Avenue). The modeling effort developed the interface for the model and the inputs for the users, and the linkages to the hydraulic model for the Rio Grande. The output, or results of the model runs, as well as other geospatial data developed in the course of the model, were delivered in the form of Arcview shape files and are also compatible with versions 3.2a or 8.1.

An aquatic habitat model was produced for the middle Rio Grande and lower Rio Chama (Bohannan-Huston et al. 2004). The analysis used two-dimensional data (georeferenced depth and velocity data collected at six sites on the Rio Grande and two sites on the Rio Chama) to simulate hydraulic conditions for a range of flow conditions, and used GIS to characterize and quantify the habitat at each flow, (as shown in Chapter 2, Figure L-2.1). At each hydraulic simulation, habitat was quantified based on the habitat-use criteria and the amount of available habitat to determine a function of habitat availability with change in discharge. This study detailed the hydraulic and habitat model methods, results, and conclusions. The results of this study are explained in the Aquatic Habitat and Hydraulic Modeling Study for the Upper Rio Grande Water Operations Model (Bohannan-Huston et al. 2004).

The Project Area was evaluated for potential effects from changing water operations at the facilities under consideration in the Project. Since no changes are proposed by the Project for the Northern and Southern Sections of the Upper Rio Grande, only the riverine and reservoir resources of the Rio Chama, Central, and San Acacia Sections were modeled and studied.

<u>Fish habitat area:</u> This is the total suitable habitat area (in square feet) for each of the species for the 40-year hydrology data set. The area was determined by combining the hydraulic simulations for each flow with the habitat suitability function for each species and life stage. The San Acacia Section is subject to variable fish habitat area because of potential diversions from the Low Flow Conveyance Channel. The *Ground Water Model* (ISC 2005) was corrected to correlate with the *Aquatic Habitat Model* used to evaluate all other river reaches. In the San Acacia Section, three scenarios were modeled to represent the

range of possible maximum diversions to the Low Flow Conveyance Channel (LFCC). The No Action Alternative was modeled for a cap of 500 cfs, 1,000 cfs, and 2,000 cfs in order to capture this range and provide diversion operations similar to the different Action Alternatives for comparative purposes. In all cases, the modeled diversions to the LFCC provide for a bypass of 250 cfs to the river channel at all times that such flows are available, with diversions to the LFCC taking place only when flows exceed 250 cfs discharge.

Duration of overbank flooding: This parameter is the average number of days within a year that water levels exceed normal flows and represents the number of days floodplain inundation. Floodplain inundation provides important nursery habitat for many larval fish species.

Area of overbank flooding: This parameter quantifies the average annual square meters of inundated floodplain habitat. Floodplain inundation provides important nursery habitat for many larval fish species.

Average # of days of 0 cfs: This parameter represents the average annual number of days when particular sections of the river are dry.

Average # of days of < 100 cfs: This parameter represents the average annual number of days where river flows are less than 100 cfs.

Average peak flow magnitude: Peak flow magnitude is a measure of flood pulse strength. This is an important cue for many fish species to initiate spawning.

Average peak flow duration: Peak flow duration is a measure of the number of days within a year where flood pulses are maximized. This is also an important cue for many fish species to initiate and maintain spawning activities.

Low Flow Augmentation: Conservation capability for augmenting low flow days of < 100 cfs in the Central and San Acacia Sections was computed by using 1/2 the median storage available at Abiquiu Reservoir (assuming this amount is potentially available for threatened and endangered species needs). Augmentation flow is defined as an additional 150 cfs release to the particular low flow event.

Variable Diversion of Water to the Low Flow Conveyance Channel (LFCC): The Action Alternatives and the No Action alternative test the potential effects of the full range of diversion to the LFCC, however, cannot model for all possible operations independently of one another. With the exception of no diversion, each of the tested operations rules is actually a range of possible operations: 0-500 cfs, 0-1,000 cfs, and 0-2,000 cfs. Operation of the LFCC is independent of other operations, making it necessary to evaluate the potential impacts of the full range of diversions considered in this Project.

Within the No Action and each Action alternatives, the actual diversion was modeled to begin only after the flow at the San Acacia gage reached a minimum of 250 cfs. Diversion would proceed to intercept any available flow above 250 cfs until diversion reached the maximum allowable flow specified for the alternative. At that point, diversions were held steady or decreased down to zero, as flow in the channel varied. Thus, flows remain steady at 250 cfs at the San Acacia gage during any modeled diversion to the LFCC. Diversions to the LFCC would vary as flows permit until the specified maximum diversion is reached, with any additional available water in the system being left in the main channel after the cap is reached. For example, Alternative I-2 with a cap of 1,000 cfs, would be modeled and operated so that when a discharge of 1,800 cfs occurs above the diversion, 1,000 cfs would be diverted, and 800 cfs would remain in the channel. But when the discharge at the diversion is less than 1,000 cfs, 250 cfs would remain in the channel and the remainder would be diverted to the LFCC.

To fully test the entire range of possible operations of the LFCC, the No Action was modeled with zero diversion and all available flow was routed through the main channel of the river. The No Action with zero diversions models most closely the current river operations. However, there are no fully comparable model runs to accurately compare every possible LFCC diversion for zero diversions every Action alternatives.

RGSM Threshold Velocity: A "threshold" velocity was determined that would minimize the downstream displacement of passively drifting Rio Grande silvery minnow eggs and larvae. This value was based on the developmental rate (dependent on water temperature) of Rio Grande silvery minnow and the reach length of interest. The threshold velocity determination (m/s) was expressed as length of fragmented river reach (m) divided by time(s) to development of swim bladder.

3.2.1.1 Impact Analysis on Riverine Resources

Margins of error occur from the use of multiple data sets and models to generate riverine analyses. For the Rio Chama and Central Sections where the historical river gage data integral to the URGWOM and aquatic habitat models is well calibrated, margins of error are small. Margins of error in the San Acacia Section, where the river bed is composed of shifting sand, may be greater than 10% due to inaccuracies introduced into the models from poor quality historic river gage data. However, the comparative analyses are all subject to the same margin of error in each river section, providing confidence in the final ranking of the alternatives relative to one another on a section-by-section basis.

Impacts of the Alternatives on Fish Habitat Availability

The six categories of indicator fish species were chosen for the model due to distinct differences in preferred habitat. Other characters which may or may not have play a part in their choice include whether they are native or not to the drainage, whether or not they are game fish, and the portion of the river continuum that would be their normal home (from headwaters to lowland meanders). Brief descriptions for each are as follows:

Rio Grande silvery minnow – a native, non-game species ranging in the middle and lower areas of the river and inhabiting shallow stream margins, side channels and lower velocity areas of the main channel where it prefers sandy bottomed areas with detritus and algae for food.

Longnose dace – a native, non-game species ranging in the upper and middle areas of the river and inhabiting gravel and cobble runs with moderate to swift flow.

Flathead chub/river carpsucker – these are native, non-game species ranging throughout the river in areas of slower runs over sandy substrate.

Channel catfish – a non-native (to the Rio Grande), game species ranging in the middle to lower river and occupying cool to warm water pools with sandy bottoms.

Brown trout – a non-native, game species ranging in upper reaches and occupying cold water areas in the deeper, slower pools.

All alternatives were compared to the No Action Alternative for relative impacts to fish habitat availability as modeled with the Aquatic Habitat Model. Results of the study are presented by river Section for the habitat categories specific to each species studied, as measured in total square feet of habitat change, by species and alternative.

Rio Chama Section

Habitat availability in the Rio Chama Section varies only slightly among the species analyzed when viewed as percent change from the No Action Alternative. On average, for all species, less than 5% difference exists between alternatives (**Table L-3.2**). The No Action Alternative performs slightly better than all Action Alternatives in the Rio Chama Section for Rio Grande silvery minnow (RGSM) habitat, but is intermediate in relative habitat available for other species. Alternative D-3 slightly outperforms the No Action Alternative in available habitat for long-nosed dace, flat head chub/carpsucker, and channel catfish, by 1.9%, 0.7%, and 1.0% respectively. Alternative I-1 outperforms the No Action Alternative and all other Action Alternatives for available habitat for RGSM than other Action Alternatives. It also shows the highest available habitat for brown trout. The direct comparison of the alternatives requires additional manipulation to determine if these modeled changes are statistically and biologically significant.

Table L-3.2 Rio Chama Section Habitat Availability (ft^2) by Species and Alternative

Alternative and percent change	Rio Chama Section				
	RG Silvery Minnow	Longnose Dace	FH Chub/ Carpsucker	Channel Catfish	Brown Trout
No Action	55,026	107,530	63,158	225,331	296,685
B-3	51,020	106,293	62,080	222,602	293,476
% change	-7.3%	-1.2%	-1.7%	-1.2%	-1.0%
D-3	53,204	109,568	63,612	227,672	294,997
% change	-3.3%	1.9%	0.7%	1.0%	-1.0%
E-3	52,790	108,788	63,168	226,474	294,164
% change	-4.1%	1.2%	0.0%	0.5%	-1.0%
I-1	53,522	108,144	63,261	225,807	298,709
% change	-2.7%	0.6%	0.2%	0.2%	1.0%
I-2	52,725	108,773	62,787	226,104	297,000
% change	-4.2%	1.2%	-0.6%	0.3%	0.0%
I-3	52,908	108,870	63,331	226,645	293,905
% change	-3.8%	1.2%	0.3%	0.6%	-1.0%

In order to understand specific trends in vegetation change in available aquatic habitat and other important measures of ecosystem impacts, the relative performance of the action alternatives was compared to the No Action Alternative using a chi-square test of significance. Chi-square has been one of the most frequently used statistical techniques in biological studies when addressing comparing vegetative communities for similarity (Sokal and Rolf 1995). The No Action observed data are used as the expected values to generate a goodness of fit test. The results of a significant chi-square indicate differences between categorical data at a given confidence level, by convention 95 percent.

A basic chi-square does not identify the specific cells in a contingency table that are causing the significant result. The adjusted chi-square residuals were examined to determine the significance of individual cells and their direction of change. Examination of the adjusted chi-square residuals is useful for understanding which specific variables are responsible for causing a chi-square to return a significant result. For each cell in a chi-square table, the adjusted chi-square residual provides a value ranging from -∞ to +∞. Values above +2 or below -2 indicate significant deviations from the expected value and can be read roughly as standard deviation units and are used to tease out the significant variables.

In order to evaluate changes in available aquatic habitat, the square feet of available aquatic habitat was generalized to meter squared units to account for the margin of error from stream gage measurements and other modeling errors. Using the square meter units, the Chi-square test returned a Chi-square of 90.0, indicating that the observed differences between the action alternatives compared to the No Action were significant overall. The contribution of each type of aquatic habitat available with each alternative is illustrated by the analysis of the chi-square residuals, shown in **Figure L-3.1**.

The results of the Chi-square test and analysis of the adjusted residuals indicates that every alternative would result in significantly less aquatic habitat suitable for the RGSM in the Rio Chama Section. Loss of available habitat for the minnow is considered an adverse impact. Alternative B-3 would result in the larges reduction in RGSM habitat relative to no action when compared to the other alternatives for this river section, but all alternatives would result in statistically significant decreases in habitat for this endangered species. The biological importance of this impact is equally significant, although not an irreversible condition. RGSM are currently extirpated from this river section, and the area does not contain designated critical habitat for the species, as will be discussed further in Section 3.6.1.1. Three alternatives would also significantly reduce habitat for brown trout: Alternatives B-3, E-3, and I-3. The adverse impacts to RGSM and brown trout appears to be related to the high storage and low channel capacity proposed with these three alternatives. Other significant impacts would be experienced by channel catfish in Alternative B-3.

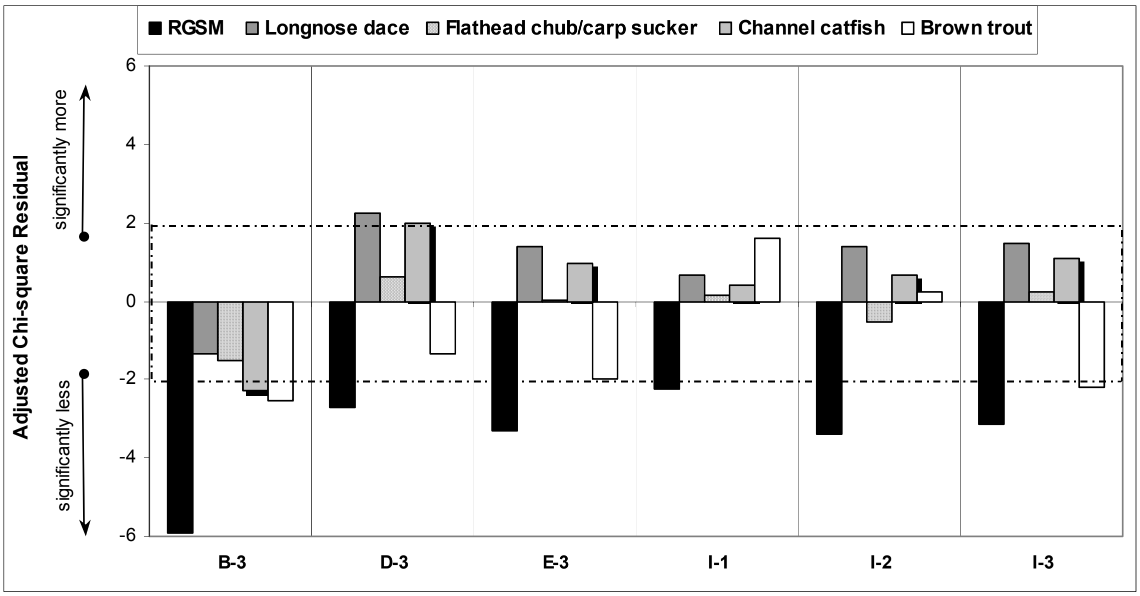


Figure L-3.1 Adjusted chi-square residual statistics for available aquatic habitat in the Rio Chama Section compared to No Action (χ^2=90.0, p=0.05).

Central Section

Habitat availability in the Central section varies about 2% or less between all species analyzed, as shown in **Table L-3.3**. Brown trout are not present in this river section. The percent change from No Action may be small, but the resulting Chi-square test indicates that the differences are significant for every action alternative and for every species considered except for one minor exception. **Figure L-3.2** graphically represents the results of the Chi square test and adjusted residual analysis. As for the Rio Chama Section, the test is for a goodness of fit for each individual action alternative compared with the No Action.

Loss of available habitat for RGSM in the Central Section is particularly large as compared to total available habitat under the No Action. The biological significance of the loss of critical habitat is a significant adverse impact of all alternatives that will be discussed further in Section 3.6 Threatened and Endangered Species.

In addition, all action alternatives would have significant negative effects on habitat for longnose dace, flathead chub, river carpsucker, and channel catfish. While the statistical significance of these results are certain, the biological importance of a change in available habitat ranging from approximately 1,000 square feet to 25,000 square feet is less certain. There is reason to believe that habitat availability is not the limiting factor for aquatic species in this Section.

San Acacia Section

Habitat availability in this reach is more pronounced between No Action and the Action alternatives. Diversions to the LFCC have a significant effect on available aquatic habitat for other species studied since the area regularly experiences low flows and diversions reduces flows in the river channel whenever these flows are greater than 250 cfs.

The San Acacia Section does not contain suitable brown trout habitat, but all other species occur. Available habitat for all other species would be significantly reduced as a percent change from the No Action alternative with no diversions to the LFCC, regardless of Action Alternative. Loss of available habitat from No Action varies between about 9 and 50% (Figure L-3.3). Some of the differences between alternatives in the section would be biologically significant. The No Action Alternative reduces available habitat for the species analyzed when operations include diversions to the LFCC, (**Figure L-3.3**). The chi-square goodness of fit test for all alternatives against the No Action with zero diversions to the LFCC, including No Action alternatives with comparable diversion levels to action alternatives, is illustrated in **Figure L-3.4**.

In addition, **Figure L-3.4**shows the comparison of the adjusted chi-square residuals for all possible alternatives in the San Acacia Section compared to one another. The chi square statistic shows extremely high levels of significant difference among the alternatives. The adjusted residuals shows that the No Action with zero diversions to the LFCC and both the No Action with 500 cfs and Alternative I-1 with 500 cfs diversions, all show much less than expected available habitat for RGSM and higher than expected habitat for longnose dace, when compared with all other alternatives.

Table L-3.3 Central Section Habitat Availability (ft^2) by Species and Alternative

Alternative	Central Section				
	RG Silvery Minnow	Longnose Dace	FH Chub/ Carpsucker	Channel Catfish	Brown Trout
No Action	1,224,029	544,523	786,861	1,792,051	N/A
B-3	1,200,176	532,409	781,522	1,778,215	N/A
% change	-1.9%	-2.2%	-0.7%	-0.8%	
D-3	1,206,690	534,747	781,238	1,780,089	N/A
% change	-1.4%	-1.8%	-0.7%	-0.7%	
E-3	1,204,042	533,924	781,130	1,778,830	N/A
% change	-1.6%	-1.9%	-0.7%	-0.7%	
I-1	1,217,438	543,593	782,243	1,786,409	N/A
% change	-0.5%	-0.2%	-0.6%	-0.3%	
I-2	1,204,580	536,795	778,619	1,777,911	N/A
% change	-1.6%	-1.4%	-1.0%	-0.8%	
I-3	1,203,105	533,143	780,127	1,776,604	N/A
% change	-1.7%	-2.1%	-0.9%	-0.9%	

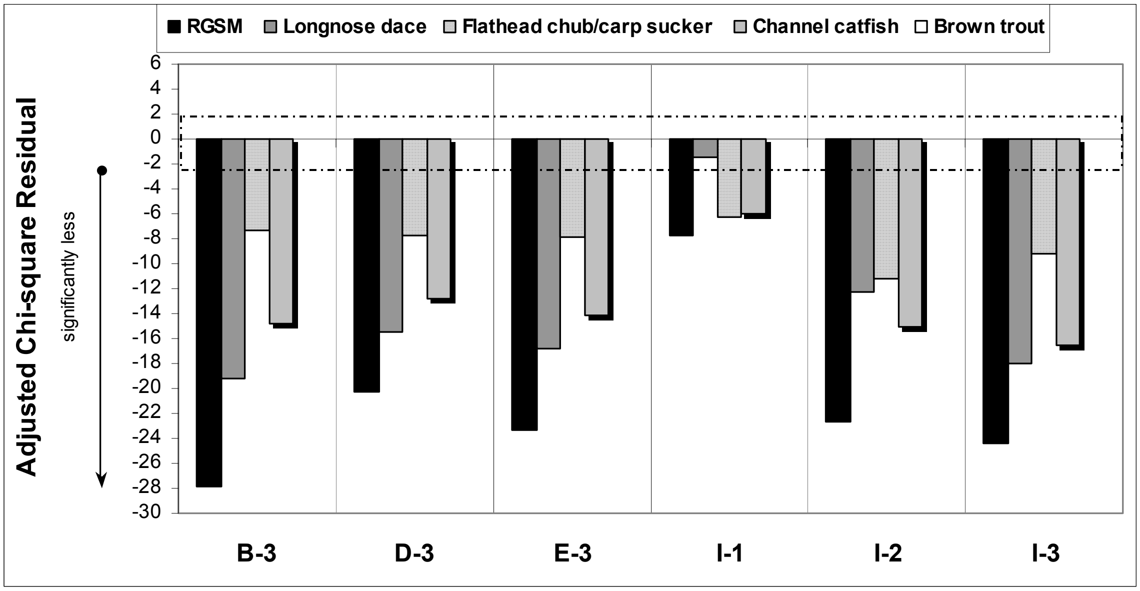


Figure L-3.2 Adjusted chi-square residual statistics for available aquatic habitat in the Central Section compared to No Action (χ^2 = 3575.4, p=0.00)

1 **Table L-3.4 Acacia Section Aquatic Habitat Model with LFCC Diversions (Bosque del Apache and San Marcial Sites)**

Fish Species	No Action Ground Water corrected	No Action with LFCC diversion of 500 cfs	Alternative I-1 with LFCC diversion of 500 cfs	No Action with LFCC diversion of 1000 cfs	Alternative I-2 with LFCC diversion of 1000 cfs	No Action with LFCC diversion of 2000 cfs	Alternative B-3 with LFCC diversion of 2000 cfs	Alternative D-3 with LFCC diversion of 2000 cfs	Alternative E-3 with LFCC diversion of 2000 cfs	Alternative I-3 with LFCC diversion of 2000 cfs
[1]RGSM	511,468	460,499	458,599	422,677	425,146	434,974	406,647	405,634	406,879	405,731
% change from comparable No Action			Ø%		+1%		-6%	-7%	-6%	-7%
[1]Longnose Dace	181,248	137,925	138,573	100,853	105,996	111,025	87,349	87,526	87,830	87,629
% change from comparable No Action			Ø%		+5%		-27%	-22%	-21%	-21%
[1]Channel Catfish	696,893	588,659	589,532	509,054	519,217	534,781	480,801	479,559	481,261	479,864
% change from comparable No Action			Ø%		+2%		-10%	-10%	-10%	-10%
[1]Flathead Chub and [2]River Carpsucker	296,372	253,103	252,771	221,554	224,589	232,052	208,223	208,176	208,789	208,257
% change from comparable No Action			Ø%		+1%		-10%	-10%	-10%	-10%

[1] Adult and Juvenile [2] Juvenile Only

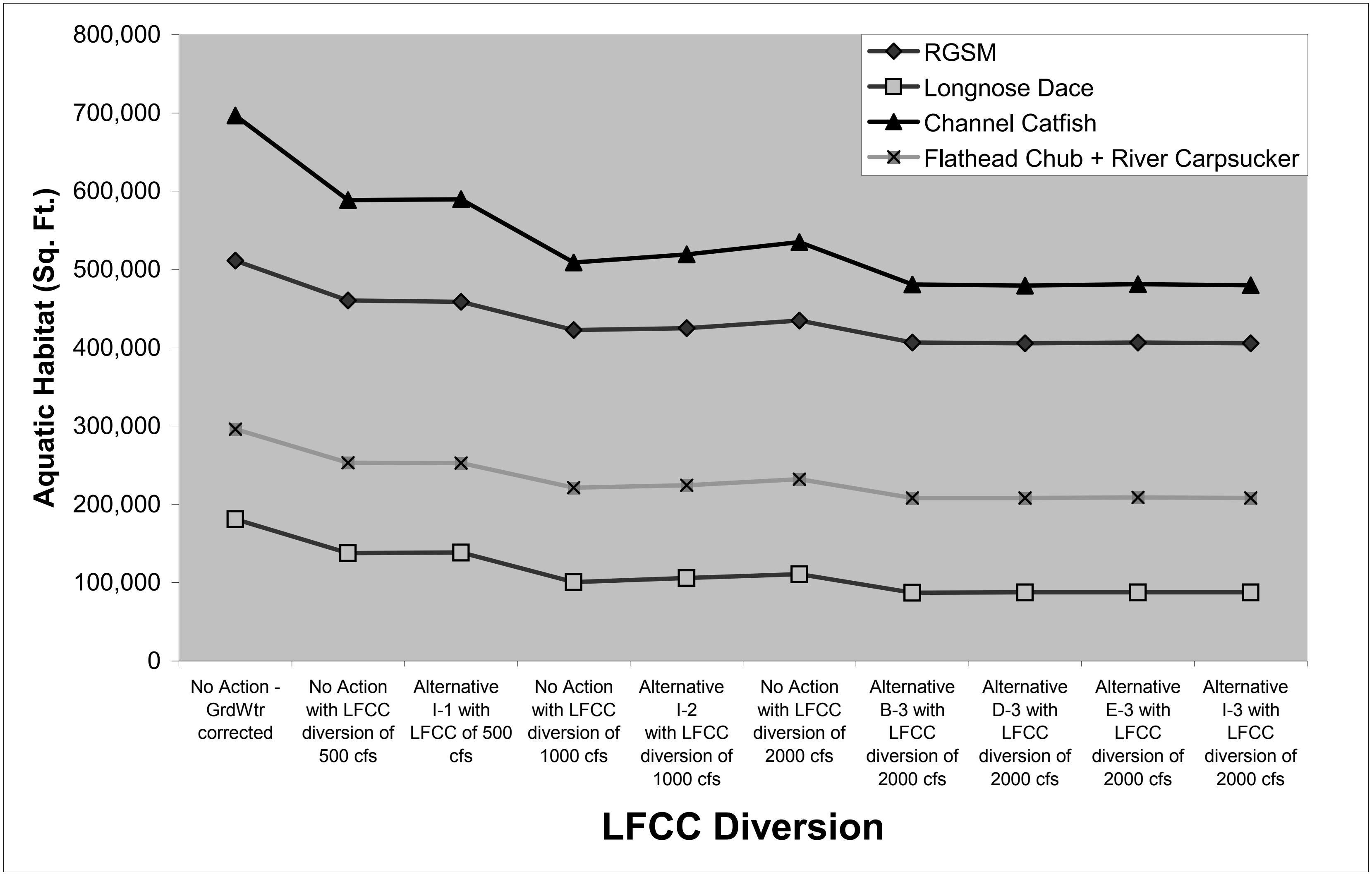


Figure L-3.3 Comparison of aquatic habitat available for indicator species in the San Acacia Section, by alternative.

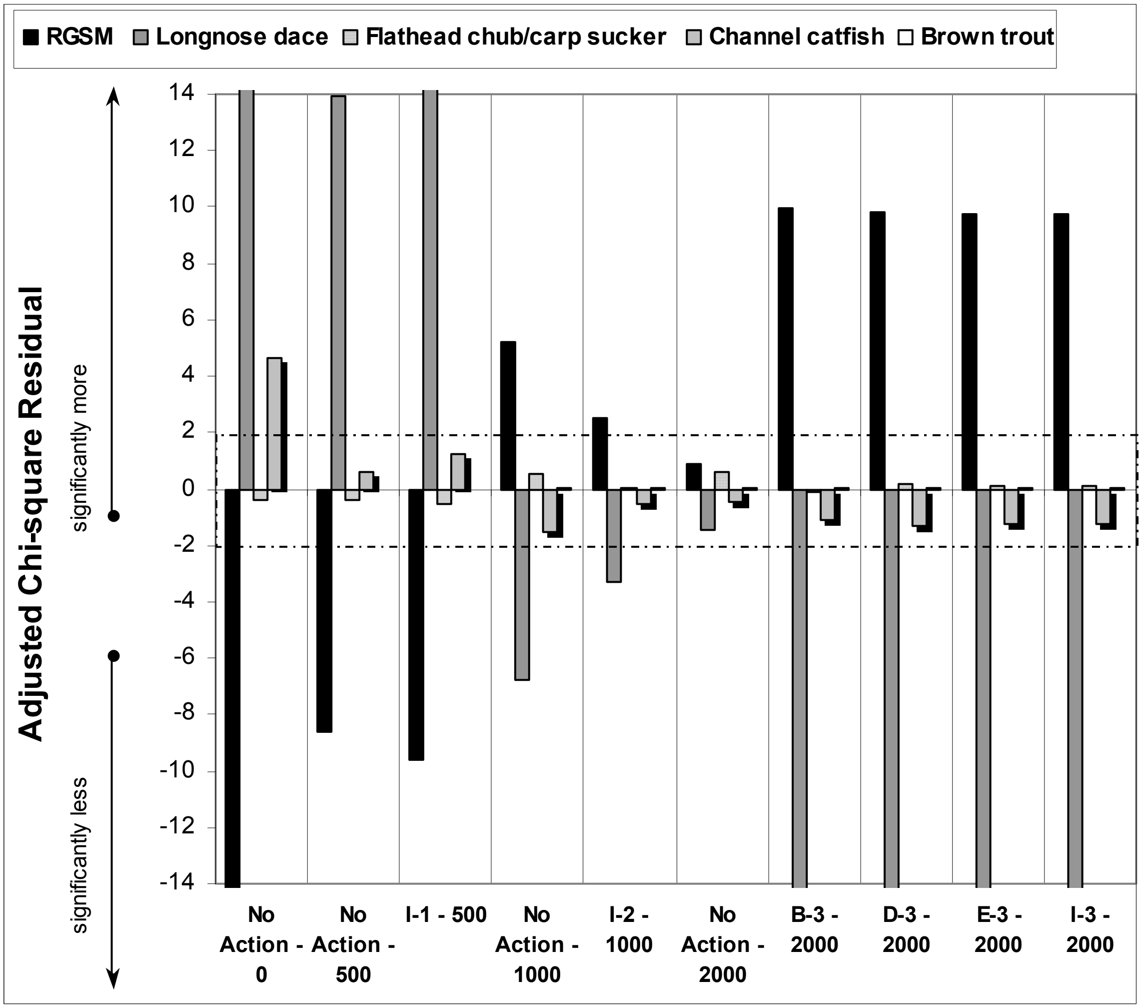


Figure L-3.4 Comparison of adjusted chi-square residuals for all alternatives for available aquatic habitat in the San Acacia Section (χ^2= 2659.4; p=0.000).

No Action Alternative with zero diversions to the LFCC most closely models the current operations of the river in all river sections, including the San Acacia Section. The reduction in absolute available habitat for all species studied across all alternatives when compared to the No Action with zero diversions at the LFCC is clear from the exceptionally large chi square value of 2,659.4. However, the data also demonstrates that there are expected differences among alternatives with the same level of diversion to the LFCC. Impacts to aquatic habitat in the San Acacia Section from any alternative would be composed of both upstream operations and the in-stream effects of LFCC diversion. In order to tease these effects apart and determine the significance of upstream impacts compared to impacts from operating the LFCC, the data were subjected to additional statistical tests, shown in **Table L-3.4** and **Figure L-3.4** through **Figure L-3.6**.

Statistical comparisons were made with data converted to square meters to account for cumulative errors in stream gages and modeling. This also has the effect of returning more conservative chi square test results. Summary statistics were evaluated to determine if the data were characterized by normal distributions for each habitat type. All modeled options for the No Action Alternative show normal distributions for fish habitat types studied.

A chi square test was run on the aquatic habitat data for the No Action options to determine the level of impact of diversion to the LFCC separate from any proposed new upstream operations changes proposed in the different action alternatives. The comparison of available aquatic habitat in the San Acacia Section under the No Action Alternative options returns a chi-square of 951.1 with $p<0.001$, demonstrating significant differences among the diversion options. The adjusted chi square residuals, shown in Figure L-3.5, show that zero diversions to the LFCC returns significantly less than the expected value for RGSM habitat and significantly more longnose dace habitat than expected

When diversions are increased to 500 cfs, the comparison still shows significantly more available longnose dace habitat than expected, but RGSM habitat is within the expected range. When diversions are increased to 1,000 cfs under the No Action Alternative, the available RGSM habitat returns the largest positive chi square residual for RGSM habitat, showing that there is significantly more available RGSM habitat than would be expected. With 1,000 cfs diversions there would be significantly less than the expected longnose dace and channel catfish habitat. No Action with 2,000 cfs diversions follows this trend, with the significantly more RGSM habitat than expected and significantly less longnose dace habitat, but not to the same levels as No Action with 1,000 cfs diversions.

These results suggest that the amount of diversion from the river channel does not have a linear relationship with habitat availability for any of the species studied, but especially for RGSM habitat and longnose dace habitat. These two habitat types are affected in opposite ways when under low flow conditions, such as when flow is decreased by diverting water to the LFCC. RGSM habitat is lower in proportion to other habitat types at high flow and longnose dace habitat is more abundant. The lower flows available in the river channel when 1,000 and 2,000 cfs diversions occur would certainly result in lower area of habitat for RGSM but would possibly create conditions that provide proportionally more RGSM habitat compared to both longnose dace and channel catfish habitat. The biological significance of the change in relative proportion of habitat area is uncertain, but may provide competitive advantages to the species with higher relative availability.

To further evaluate the interaction between complex upstream operations proposed in the action alternatives from the different diversions to the LFCC in the San Acacia Section, comparative tests were performed on each action alternative paired with the modeled No Action Alternative with equal diversions to the LFCC. The chi-square goodness of fit was used to examine the data available habitat data from Alternatives B-3, D-3, E-3, and I-3, which all have 2,000 cfs diversions to the LFCC, compared with equal diversions in the No Action with 2,000 cfs diversions. The results are displayed **Figure L-3.6**.

The No Action modeled with 500 cfs diversions at the LFCC and Alternative I-1, which caps diversions to the LFCC at 500 cfs, were compared. The comparison shows that Alternative I-1 provides similar levels of aquatic habitat for all species studied, when compared with No Action with equal diversions to the LFCC. The results of a chi-square goodness of fit test from Alternative I-1 indicate no significant difference from No Action ($X^2 = 1.2$, $p = 0.883$). Although modeled data are not available for available habitat when this or other Action Alternatives are operated with no diversions to the LFCC, it is probable that Alternative I-1 would not result in increased available habitat for these species if no diversions were made, based on the performance at 500 cfs diversions.

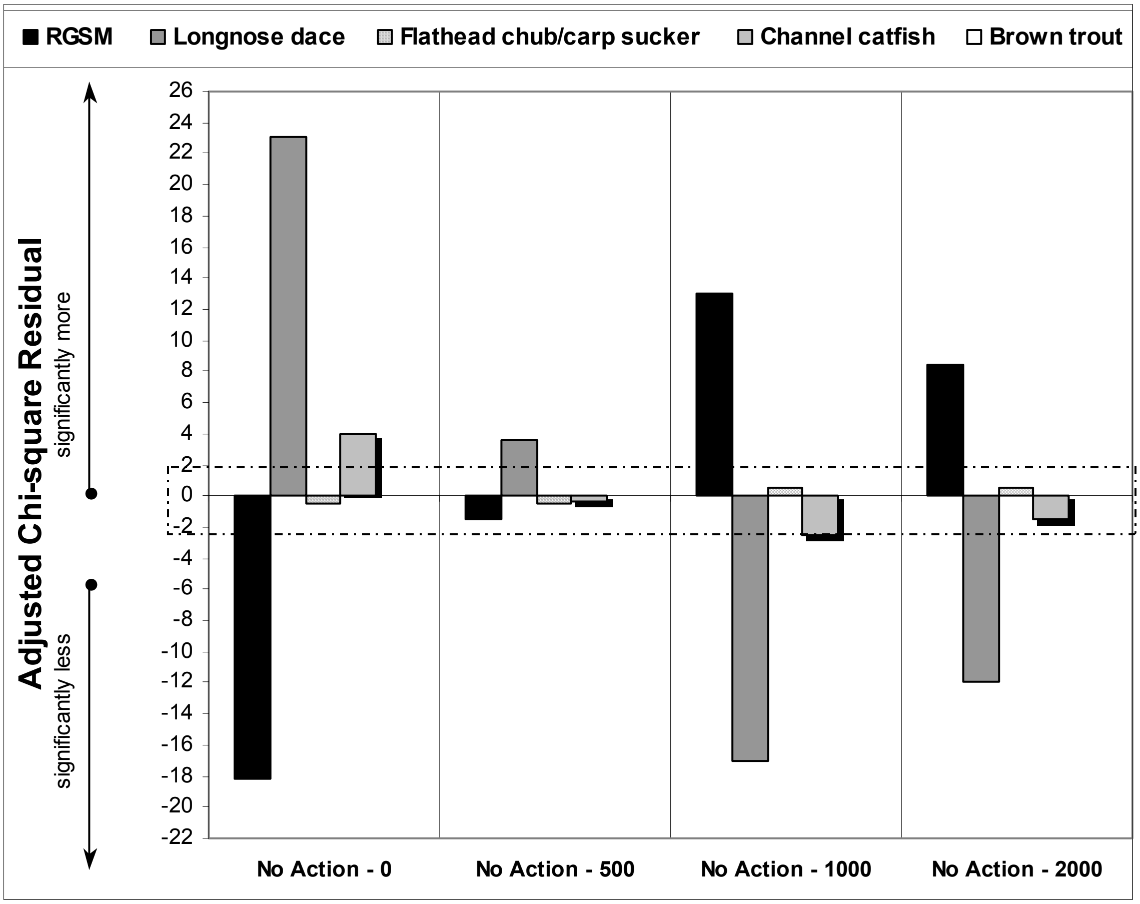


Figure L-3.5 Comparison of available aquatic habitat in the San Acacia Section under No Action Alternative with variable diversions to the LFCC (χ^2= 951.1, p= 0.000).

Alternative I-2, which caps diversions to the LFCC at 1,000 cfs but has different upstream storage and channel capacity compared with No Action and I-1, performs the best relative to the No Action Alternative when modeled with equal diversions. This alternative would provide 1% increase in available habitat for RGSM, 5% increase for longnose dace, 2% increase for flathead chub and river carpsucker, and 1% increase in habitat for channel catfish, when compared with similar diversions under the No Action Alternative. These increases in habitat are significant ($X^2 = 48.3$, $p < 0.001$).

Although modeled data are not available for available habitat when this or other Action Alternatives are operated with no diversions to the LFCC, it is probable that Alternative I-2 would increase available habitat for these species if no diversions were made, based on the performance with diversions capped at 1,000 cfs.

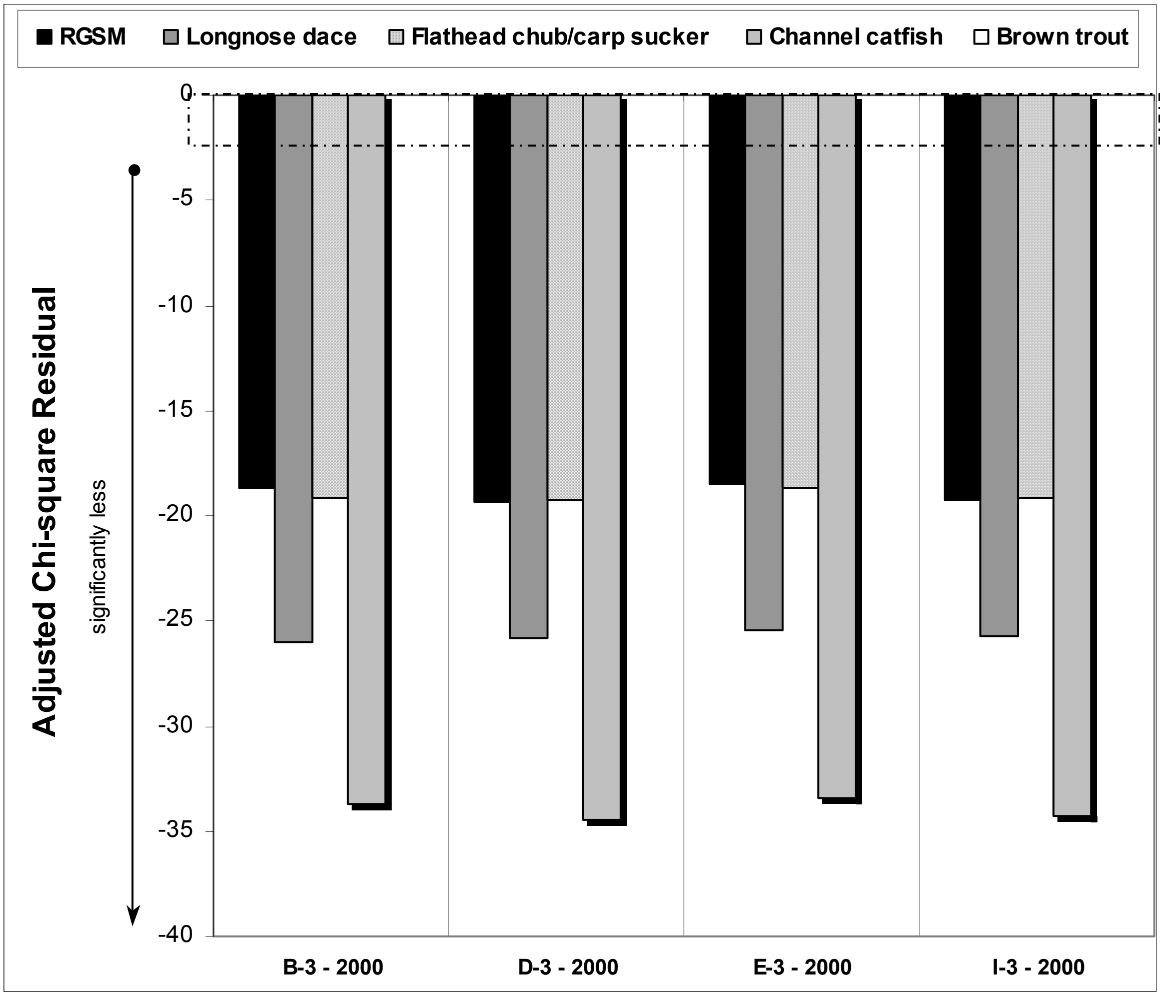


Figure L-3.6 Comparison of available aquatic habitat in the San Acacia Section chi-square goodness of fit adjusted residuals compared to No Action with 2,000 cfs diversions to LFCC (χ^2 = 5,502.4, p=0.000).

Alternatives B-3, D-3, E-3, and I-3 would all significantly reduce available habitat for the species analyzed when compared with No Action Alternative with equal diversions to the LFCC, as shown in Figure 3.6. The chi-square result shows significant changes for all action alternatives with 2,000 cfs diversions when compared to the No Action with equal diversions.

The longnose dace incurred the highest reduction of habitat in Alternative D-3, approximately 27 percent, the second highest overall reduction in habitat for this species among all alternatives and river sections in this study. Available habitat for other species studied decreased by 10% when compared with No Action with equal diversions to LFCC, and all losses are shown to be statistically significant. The reduction in RGSM habitat is statistically significant, among these Action Alternatives, ranging from six to 7% reductions when compared with No Action with similar (2000 cfs) diversions. Loss of habitat may result in potentially adversely impacts to all species, although it is uncertain if habitat availability is limiting for any of the species studied. In addition, reduced habitat availability might be offset by the improved relative proportion of RGSM habitat compared to other species, shown in the analysis of the No Action Alternative with variable diversions (**Figure L-3.5**).

Impacts Of Low Flow And Low Flow Augmentation

Discharges of less than 100 cfs and zero discharge are currently experienced in the study area and are detrimental to aquatic species. Drought, diversions, and seepage contribute to low flow conditions. Evaluation of discharges at the multiple gages during the 40-year time sequence shows that the No Action and Action Alternatives result in different amounts of low flow days and in different amounts of stored upstream water available for augmenting low flows and reducing adverse impacts.

The No Action Alternative would not provide low flow augmentation during the spring and summer months due to storage and release conditions and limitations at Abiquiu and Cochiti reservoirs. Under the No Action alternative, storage of the current year's spring runoff that has not been released from Abiquiu Dam by July 1 is locked as carry over storage at Abiquiu reservoir until October 31. This carry over storage must be released between October 31st and March 31st, when river flows are generally reliable and it is least beneficial biologically. Since the No Action Alternative has zero ability to augment low flow all Action Alternatives offer an improvement over No Action.

Rio Chama Section

Low flow is not an issue for the Rio Chama Section, since flows are reliable in this area and carry over storage is released as inflow to Cochiti reservoir and stored for release to the Central Section and San Acacia Section.

Central Section

The number of days predicted for zero flow or flows less than 100 cfs in the Central Section does not vary to any extent among the alternatives. Days with zero flow in the Central Section vary from 15 in the No Action and Alternative I-1 to 16 days with all other alternatives, as shown in Figure L-3.7. Low flow days at less than 100 cfs are 32 or 33 across all alternatives, including the No Action. The ability to augment low flow and zero flow days, however, varies widely among the alternatives according to the storage and the channel capacity options available. The No Action Alternative performs the worst, since low flow augmentation is not possible. A total of 99 days with flows less than 100 cfs would be possible. Alternatives B-3, D-3, E-3, I-2, and I-3 all provide adequate opportunity, in the form of stored water in Abiquiu Reservoir, to offset all low flow days. Only Alternative I-1 is unable to deliver sufficient low flow augmentation, resulting in a 32-day shortfall in the Central Section.

Low flow days are very high in the San Acacia Section, ranging from 99 in the No Action Alternative to 110 days in some Action Alternatives. As modeled, only Alternative B-3 provides sufficient low flow augmentation to completely offset the number of predicted days at zero or less than 100 cfs in both the Central and San Acacia sections. This alternative would provide benefits to riverine habitat and fish communities from continuous flows during the drought years modeled. All other alternatives would not have enough augmentation days to cover the predicted number of low flow days for the San Acacia Section and would produce less mitigation to fish communities.

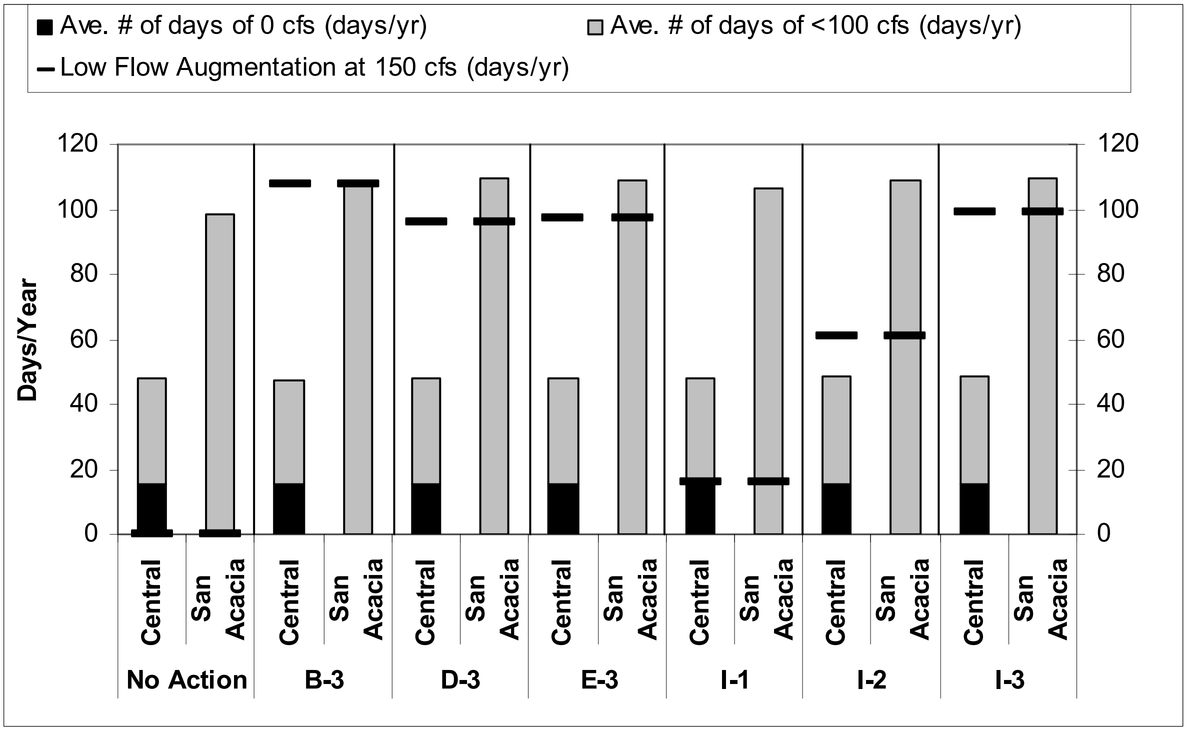


Figure L-3.7 Low flow and zero flow days predicted by the URGWOM Model, with estimated days of low flow augmentation, by alternative.

Impacts on Peak Flow Characteristics

Changes in the duration and magnitude of peak flows can affect the success of spawning and recruitment of aquatic species. As a result, any statistically significant differences may also have biological significance for the affected species if the baseline peak flow condition is known to initiate spawn, and produce reliable recruitment.

The No Action Alternative exhibits high average magnitude of peak flows and duration of peak flows in the Rio Chama, Central, and San Acacia sections compared with all Action Alternatives (**Figure L-3.8**). Chi-square goodness of fit test of the peak flow magnitude and duration of the alternatives was conducted. The chi-square returned a value of 3731.6 with $p=<0.000$ for the comparison of peak flow magnitude, indicating that significant differences occur when the alternatives are compared to the No Action with zero diversions to the LFCC. The duration of the peak flow also returned a significant chi square value: 22.6 with $p=0.012$. As with aquatic habitat tests, the adjusted chi square residuals were evaluated to understand the specific impacts to the fish species studied, by alternative.

Duration of peak flows would not change significantly in the Rio Chama Section, regardless of alternative. But the magnitude of the peak would be reduced significantly in all alternatives. Alternative I-2 would experience peak flow magnitude and duration most similar to the No Action Alternative in the Rio Chama. The biological effects in Rio Chama would probably be unaffected.

Changes in the magnitude and duration of peak flows in the Central Section are statistically significant, ranging from significant reductions in I-2, I-3, B-3, and D-3, to no significant change with Alternatives E-3 or I-1. The duration of peak flows is essentially unchanged by the alternatives, but changes in magnitude accounts for most of the chi square critical value in the Central Section.

Changes in magnitude and duration of peak flows would be most pronounced in the San Acacia Section, with all alternatives returning negative values in both duration and magnitude of the peak flow compared to the No Action Alternative with zero diversions to the LFCC. Peak flow magnitude would range from a decrease of 24% with Alternatives I-1 and I-2, to a decrease of 48% in Alternative I-3. When compared to No Action with variable diversions, the alternatives all still would result in significant decreases in flow magnitude and duration, as shown in **Table L-3.4**. No Action alternatives with 500, 1,000, and 2,000 cfs diversions would also result in significant decreases in the magnitude and duration of the peak flow.

The biological affects of decreasing the magnitude and duration of peak flows in the San Acacia Section would be unpredictable and potentially adverse for the species studied. Peak flow characteristics in the San Acacia Section are probably being influenced by the diversions to the LFCC, resulting in the large difference compared to No Action Alternative with no diversions. The peak flow characteristics of the No Action Alternative with variable diversions to the LFCC were not modeled and therefore could not be compared to the Action Alternatives.

Summary of Impacts to Riverine Habitat, by Alternative

No Action

The No Action Alternative without diversions to the LFCC out performed all alternatives for providing RGSM habitat in all areas, but would not provide proportionally as much RGSM habitat as other alternatives, as indicated by the previous discussions and summary data in **Table L-3.2** and **Table L-3.3**. Habitat availability for other species included in this study was intermediate for the No Action Alternative. The No Action Alternative with zero diversions to the LFCC also provides the highest available peak flow magnitude and duration for all river sections, a factor that is significant to some of the species studied

Modeled for variable diversions the No Action Alternative continues to provide statistically significant increases in aquatic habitat for the fish species studied and significantly higher levels of peak flow magnitude and duration in all river sections when compared to the action alternatives with equal diversions. In particular, the No Action Alternative with variable flows performed significantly better for aquatic habitat measures in the San Acacia Section.

Unfortunately, the No Action does not provide steady flows in some sections during droughts, and the Central and San Acacia Sections would experience many low flow, or zero flow, days that could not be augmented with upstream storage as modeled in this study.

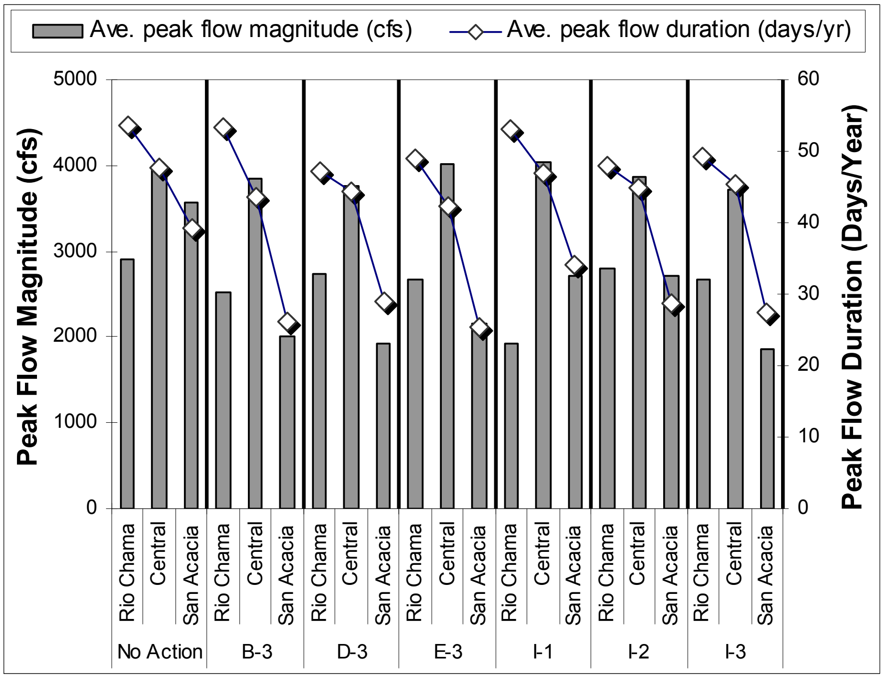


Figure L-3.8 Impacts of the Alternatives on Peak Flow Characteristics

Table L-3.4 Change in Peak Flow Magnitude and Duration for the San Acacia Section with LFCC Diversions (percent Change Relative to No Action with Equal Diversion to LFCC)

Alternative	LFCC Diversion	Peak Mag	Peak Duration
No Action	0 Diversion	3,578	39.3
No Action	500 cfs	3,205	33.6
I-1	500 cfs	2,713	34.1
	% change from No Action with 500 cfs	-15%	-1.5%
No Action	1,000 cfs	2,774	29.0
I-2	1,000 cfs	2,703	28.8
	% change from No Action with 1,000 cfs	-2.6%	-0.7%
No Action	2,000 cfs	2,398	26.4
B-3	2,000 cfs	2,006	26.2
	% change from No Action with 2,000 cfs	-16.3%	-0.8%
D-3	2,000 cfs	1,922	28.9
	% change from No Action with 2,000 cfs	-19.8%	+10.2%
E-3	2,000 cfs	2,153	25.5
	% change from No Action with 2,000 cfs	-10.2%	-3.4%
I-3	2,000 cfs	1,860	27.5
	% change from No Action with 2,000 cfs	-22.4%	+4.2%

Alternative B-3

Alternative B-3 is one of the lowest ranked alternatives compared to the No Action Alternative because it results in a statistically significant reduction of aquatic habitat for all studied species and in all river Sections. This alternative would have significant impacts on longnose dace in the San Acacia Section, based on the aquatic habitat model. It also results in significant decreases in the magnitude and duration of peak flows which provide important biological stimulus to fish species. However, this alternative significantly reduces the number of lowest low flow and zero flow days in the models and provides the best ability to augment flows and avoid stream intermittency in the Central and San Acacia Sections. Regardless of diversions to the LFCC, Alternative B-3 would result in adverse impacts to aquatic habitat.

Alternative D-3

Alternative D-3 is one of the highest ranked alternatives for providing the low levels of impact to aquatic habitat for studied species in the Rio Chama Section and Central Section. However, this alternative would significantly reduce habitat for longnose dace in the San Acacia Section compared to the No Action Alternative with equal diversion to the LFCC. It also results in significant decreases in the magnitude and duration of peak flows, especially in the San Acacia Section. In addition, this alternative has more low flow and zero flow days than other alternatives and the No Action Alternative. Low flow augmentation would not be able to off set all the low flow days in the San Acacia Section, under Alternative D-3.

Alternative E-3

Alternative E-3 provides approximately the same amount of habitat for the aquatic species studied in all sections compared with the No Action Alternative. The one exception is the aquatic habitat available in the San Acacia Section compared with No Action with equal diversions to the LFCC. In this case, Alternative E-3 would reduce RGSM habitat by 7% and reduce longnose dace habitat by 21 percent.

Alternative I-1

Alternative I-1 provides the best aquatic habitat for the species studied in the Rio Chama and Central Sections. In the San Acacia Section, this alternative provides the same amount of modeled aquatic habitat for all species as the No Action with equal diversions to the LFCC. I-1 did not perform well in other aquatic measures, however. This alternative would result in a significantly lower magnitude of peak flow in the Rio Chama Section and San Acacia Section, possibly resulting in adverse effects to spawning fish. In addition, this alternative would have very little opportunity for low flow augmentation, resulting in approximately 90 low flow days being un-mitigated in the San Acacia Section, and 32 low flow or zero flow days in the Cnetral Section being un-mitigated with augmented flows. In addition, brown trout habitat increases slightly under Alternative I-1. Alternative I-1 performs the best among the Action Alternatives for the RGSM in the San Acacia Section and the Rio Chama, with neutral impacts in the Central Section.

Alternative I-2

Alternative I-2 would result in slightly lower habitat for fish species, such as RGSM and longnose dace, in the San Acacia Sections. These differences from the No Action Alternative are moderate and may not be biologically significant. In the San Acacia Section, Alternative I-2 is the best performing alternative, providing slight increases in aquatic habitat for all studied species, when compared to No Action with 1,000 cfs diversions. I-2 would be able to offset predicted low flow days in the San Acacia Section for 61 days, but an additional 48 low flow days would not be mitigated. The primary adverse effect of this alternative is that the magnitude of the peak flow in San Acacia Section would be significantly lower than No Action with zero diversions to the LFCC. In addition, brown trout habitat does not change under Alternative I-2.

Alternative I-3

Alternative I-3 provides approximately the same amount of habitat for the aquatic species studied in all sections compared with the No Action Alternative. The one exception is the aquatic habitat available in the San Acacia Section compared with No Action with equal diversions to the LFCC. In this case, Alternative I-3 would reduce RGSM habitat by 7% and reduce longnose dace habitat by 21 percent.

3.2.2 *Reservoir Habitat Criteria Evaluation Methods*

Net reservoir elevation rate of change: The rate of change in reservoir elevation is a measure of habitat stability. Habitat stability is especially important in the spring months for successful reproduction of many fish species. These species generally spawn in the submerged vegetation along shoreline habitats (littoral zones) that are most vulnerable to drying during reservoir elevation fluctuations.

Reservoir elevation rate of change was determined for each alternative by separating the forty-year model into individual years and then extracting data for the spring months (April-June) for each reservoir. Spring averages were calculated by taking the forty-year average of each day occurring in the spring months. Values closest to zero represent reservoir stability.

Area of littoral habitat: The amount of littoral habitat is a measure of available shoreline zones used by reservoir fishes for spawning. Littoral habitat is especially important in the spring for nursery and foraging habitats, and successful reproduction for many reservoir fish species.

Data to calculate the area of littoral habitat was only available for Abiquiu Reservoir. The bathymetry, or three-dimensional shape of the reservoir, and the reservoir elevation ranges for each alternative was determined. The resultant area of littoral habitat was extrapolated and the number of days in ten-foot reservoir elevation ranges was calculated. The value represents the maximum amount of littoral habitat in acres that is available under each alternative and the respective days at which the reservoir was within the ten-foot elevation ranges (acre days). High values represent an increase in littoral habitat.

Reservoir exchange rate: The rate at which water is exchanged in a reservoir is an indirect measure of the potential productivity of the system. Low exchange rates are generally associated with higher productivity and thus better conditions for the fishery.

Exchange rates were calculated by dividing the reservoir volume by the average annual discharge. The forty-year average annual discharge was calculated by converting the average daily discharge into an average annual discharge for each year (2003-2042). These forty values were then averaged. Low values represent lower exchange rates and higher potential productivity. The exchange rate is described in greater detail in the Biological Technical Report (2004).

3.2.2.1 Impact Analysis on Reservoir Resources

No Action

Reservoir impacts are evaluated by comparing the level of change (impact) under each action alternative to the existing conditions found under No Action. For impacts to littoral habitats summary data are found in **Figure L-3.9**. This figure illustrates the amount of potential littoral (acres) found at different reservoir elevations. Discussions for each alternative below use this analysis for impacts to littoral habitat.

Action Alternative B-3

Platoro Reservoir
Action alternatives would have no impact on this reservoir.

Heron Reservoir
Under this alternative, the reservoir elevation is the second most stable level as compared to the other action alternatives and more stable than current conditions. No data were available for this reservoir to

evaluate the impact of this alternative on littoral habitat. This alternative would result in the lowest rate of water exchange in Heron Reservoir and could result in positive impacts to the fishery.

Abiquiu Reservoir
Under this alternative, the reservoir elevation would be the third most stable level as compared to the other action alternatives. The impact of this alternative on littoral habitat would be minimal. This alternative would result in the lowest rate of water exchange in the reservoir as compared to the other action alternatives. However, this rate would be substantially greater than the current rate of exchange and could result in negative impacts to the fishery.

Cochiti Reservoir
Under this alternative, the reservoir elevation would be the second most stable level as compared to the other action alternatives and more stable than current conditions. No data was available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative would have no impact on the rate of water exchange in the reservoir as compared to current operations.

Jemez Canyon Reservoir
Action alternatives would have no impact on this reservoir.

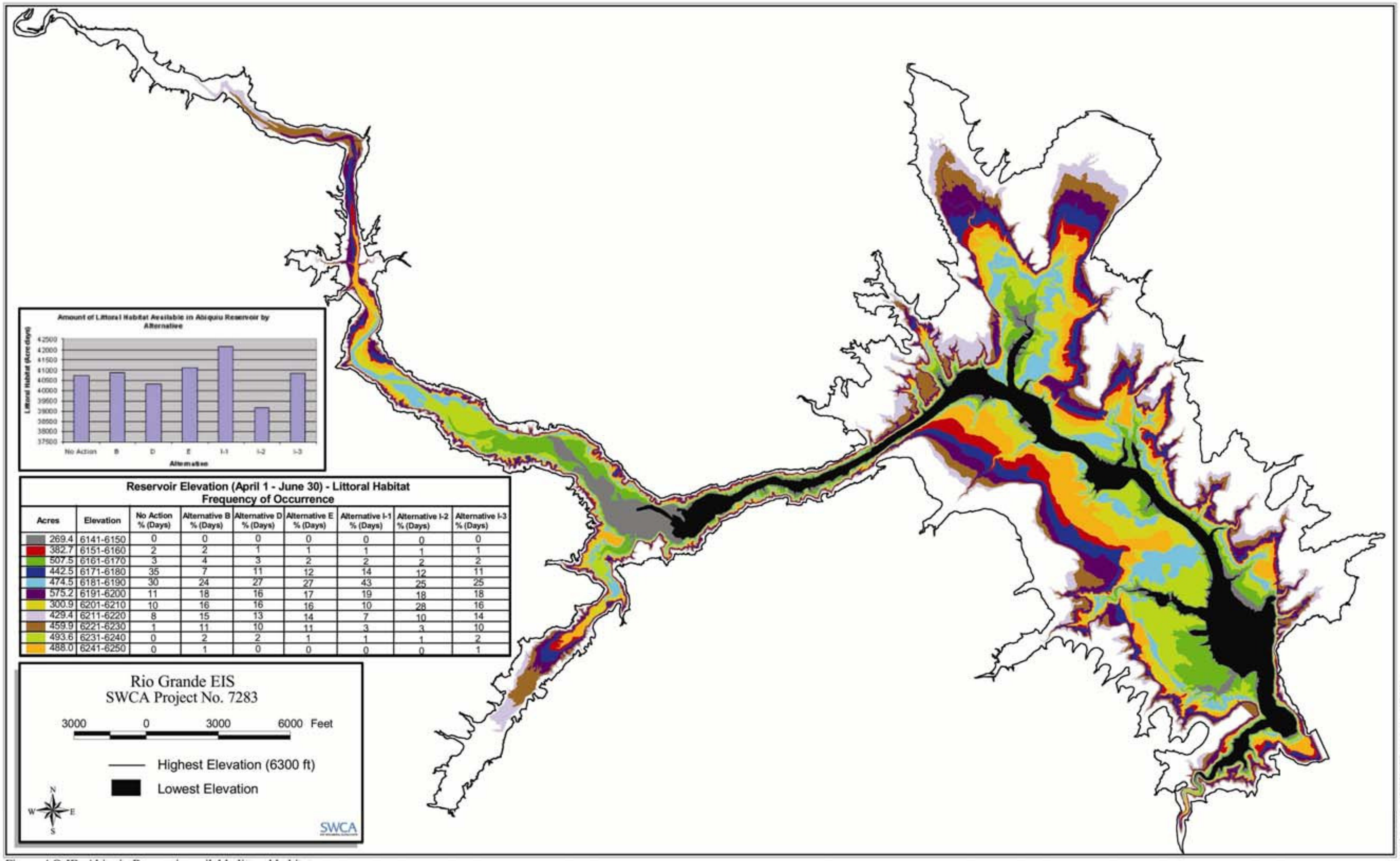
Elephant Butte Reservoir
Action alternatives would have no impact on this reservoir.

Caballo Reservoir
Action alternatives would have no impact on this reservoir.

Action Alternative D-3

Platoro Reservoir
Action alternatives would have no impact on this reservoir.

Heron Reservoir
Under this alternative, the reservoir elevation would be the most stable level as compared to the other action alternatives and more stable than current conditions. No data were available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative would result in the second lowest rate of water exchange in the reservoir and could result in positive impacts to the fishery relative to current operations.



Reservoir Elevation (April 1 - June 30) - Littoral Habitat Frequency of Occurrence

Acres	Elevation	No Action % (Days)	Alternative B % (Days)	Alternative D % (Days)	Alternative E % (Days)	Alternative I-1 % (Days)	Alternative I-2 % (Days)	Alternative I-3 % (Days)
269.4	6141-6150	0	0	0	0	0	0	0
382.7	6151-6160	2	2	1	1	1	1	1
507.5	6161-6170	3	4	3	2	2	2	2
442.5	6171-6180	35	7	11	12	14	12	11
474.5	6181-6190	30	24	27	27	43	25	25
575.2	6191-6200	11	18	16	17	19	18	18
300.9	6201-6210	10	16	16	16	10	28	16
429.4	6211-6220	8	15	13	14	7	10	14
459.9	6221-6230	1	11	10	11	3	3	10
493.6	6231-6240	0	2	2	1	1	1	2
488.0	6241-6250	0	1	0	0	0	0	1

Figure AQ-IB. Abiquiu Reservoir available littoral habitat.

Figure L-3.9 Abiquiu Reservoir available habitats

Abiquiu Reservoir
Under this alternative, the reservoir elevation would be the least stable as compared to the other action alternatives and less stable than current conditions. This alternative (as well as I-3) would result in the greatest littoral habitat availability, even greater than current conditions, and could have a positive impact on the fishery. This alternative (as well as E-3) would result in the second lowest rate of water exchange in the reservoir as compared to the other action alternatives. However, this rate would be greater than the current rate of exchange and could result in negative impacts to the fishery.

Cochiti Reservoir
Under this alternative, the reservoir elevation would be the third most stable level as compared to the other action alternatives and more stable than current conditions. No data was available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative would have no impact on the rate of water exchange in the reservoir as compared to current operations.

Jemez Canyon Reservoir
Action alternatives would have no impact on this reservoir.

Caballo Reservoir
Action alternatives would have no impact on this reservoir.

Action Alternative E-3

Platoro Reservoir
Action alternatives would have no impact on this reservoir.

Heron Reservoir
Under this alternative (as well as I-3), the reservoir elevation would be the least stable as compared to the other action alternatives and less stable than current conditions. No data were available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative (as well as I-1, I-2, and I-3) would not impact the rate of water exchange in the reservoir relative to current operations.

Abiquiu Reservoir
Under this alternative, the reservoir elevation would be the fourth most stable as compared to the other action alternatives and less stable than current conditions. This alternative (as well as I-1 and I-2) would result in the second greatest littoral habitat availability, greater than current conditions, and could have a positive impact on the fishery. This alternative (as well as D-3) would result in the second lowest rate of water exchange in the reservoir as compared to the other action alternatives. However, this rate would be greater than the current rate of exchange and could result in negative impacts to the fishery.

Cochiti Reservoir
Under this alternative, the reservoir elevation would be the most stable as compared to the other action alternatives and more stable than current conditions. No data was available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative would have no impact on the rate of water exchange in the reservoir as compared to current operations.

Jemez Canyon Reservoir
Action alternatives would have no impact on this reservoir.

Elephant Butte Reservoir
Action alternatives would have no impact on this reservoir.

Caballo Reservoir
Action alternatives would have no impact on this reservoir.

Action Alternative I-1

Platoro Reservoir
Action alternatives would have no impact on this reservoir.

Heron Reservoir
Under this alternative, the reservoir elevation level would be the third most stable as compared to the other action alternatives and even more stable than current conditions. No data were available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative (as well as E-3, I-2, and I-3) would not impact the rate of water exchange in the reservoir relative to current operations.

Abiquiu Reservoir
Under this alternative, the reservoir elevation would be the most stable as compared to the other action alternatives but substantially less stable than current conditions. This alternative (as well as E-3 and I-2) would result in the second greatest littoral habitat availability, greater than current conditions, and could have a positive impact on the fishery. This alternative would result in the third lowest rate of water exchange in the reservoir as compared to the other action alternatives. However, this rate would be substantially greater than the current rate of exchange and could result in negative impacts to the fishery.

Cochiti Reservoir
Under this alternative, the reservoir elevation would be the least stable as compared to the other action alternatives and less stable than current conditions. No data was available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative would substantially increase the rate of water exchange in the reservoir as compared to current operations and could result in negative impacts to the fishery.

Jemez Canyon Reservoir
Action alternatives would have no impact on this reservoir.

Elephant Butte Reservoir
Action alternatives would have no impact on this reservoir.

Caballo Reservoir
Action alternatives would have no impact on this reservoir.

Action Alternative I-2

Platoro Reservoir
Action alternatives would have no impact on this reservoir.

Heron Reservoir
Under this alternative, the reservoir elevation level would be the fourth most stable as compared to the other action alternatives but is less stable than current conditions. No data were available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative (as well as E-3, I-1, and I-3) would not impact the rate of water exchange in the reservoir relative to current operations.

Abiquiu Reservoir
Under this alternative, the reservoir elevation would be the second most stable as compared to the other action alternatives but substantially less stable than current conditions. This alternative (as well as E-3 and I-1) would result in the second greatest littoral habitat availability, even greater than current conditions, and could have a positive impact on the fishery. This alternative would result in the fourth lowest rate of water exchange in the reservoir as compared to the other action alternatives. However, this rate would be substantially greater than the current rate of exchange and could result in negative impacts to the fishery.

Cochiti Reservoir
Under this alternative, the reservoir elevation level would be the fifth most stable as compared to the other action alternatives and more stable than current conditions. No data was available for this reservoir to

evaluate the impact of this alternative on littoral habitat. This alternative would substantially increase the rate of water exchange in the reservoir as compared to current operations.

Jemez Canyon Reservoir
Action alternatives would have no impact on this reservoir.

Elephant Butte Reservoir
Action alternatives would have no impact on this reservoir.

Caballo Reservoir
Action alternatives would have no impact on this reservoir.

Action Alternative I-3

Platoro Reservoir
Action alternatives would have no impact on this reservoir.

Heron Reservoir
Under this alternative (as well as E-3), the reservoir elevation level would be the least stable as compared to the other action alternatives and less stable than current conditions. No data were available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative (as well as E-3, I-1, and I-2) would not impact the rate of water exchange in the reservoir relative to current operations.

Abiquiu Reservoir
Under this alternative, the reservoir elevation would be the fifth most stable as compared to the other action alternatives but substantially less stable than current conditions. This alternative (as well as D-3) would result in the greatest littoral habitat availability, even greater than current conditions, and could have a positive impact on the fishery. This alternative would result in the highest rate of water exchange in the reservoir as compared to the other action alternatives. This rate of exchange could result in negative impacts to the fishery.

Cochiti Reservoir
Under this alternative, the reservoir elevation level would be the fourth most stable as compared to the other action alternatives and more stable than current conditions. No data was available for this reservoir to evaluate the impact of this alternative on littoral habitat. This alternative would substantially increase the rate of water exchange in the reservoir as compared to current operations, and therefore negatively impact the fishery.

Jemez Canyon Reservoir
Action alternatives would have no impact on this reservoir.

Elephant Butte Reservoir
Action alternatives would have no impact on this reservoir.

Caballo Reservoir
Action alternatives would have no impact on this reservoir.

3.3 *Riparian Resources*

3.3.1 *Methods of Assessing Impacts*

The primary tools used in the ecological analysis included vegetation inventory and classification maps from the year 2002, FLO-2D models for the Rio Chama, Central and San Acacia Sections, an Aquatic Habitat Model developed by Miller Ecological Consultants, Inc., and other current data sets. Many of the data sets depend on modeled data, or are from various sources. Therefore, the quality and limitations of each data set were determined and entered into the Decision Criteria Matrix, allowing the teams to explore the sensitivity of each measure and its relative uncertainty.

Biological Impact Analysis Tools and Uncertainty

All of the alternatives, including No Action, were evaluated in the Decision Support Matrix to determine their positive and negative impacts to biological resources. The primary tools for estimating biological effects included the URGWOM Planning Model, Hink and Ohmart Vegetation Classification and Mapping (both 1982 data and the adapted methods applied in 2002-2003), and FLO-2D overbank inundation models for the Rio Grande and Rio Chama generated in 2004. The combined modeling and mapping efforts provided information for the analysis, but only provided one view of operations within a wide range of operations at each facility.

The FLO-2D Model of overbank inundation is the most precise and accurate in the Rio Chama and Central Sections of the Project, and less reliable in the San Acacia Section due to streambed instability. Riparian and Aquatic habitat assessments that depend on FLO-2D modeled data are therefore less reliable in the San Acacia Section than impacts assessments elsewhere in the project area. A complete description of the data sources and data accuracy is provided in Appendix R.

Finally, the Bureau of Reclamation hydrologists ran the Bureau's HEC-RAS model for flows between 0 and 7500cfs (flow at the San Marcial Gage) for the reach between the south boundary of the Bosque del Apache Refuge and the power lines at the full pool of Elephant Butte Reservoir. The model results provided a water surface elevation at multiple cross-sections along the river. The HEC-RAS cross-sections were overlaid in a GIS on the FLO-2D grid layer and merged. Using the GIS, it was determined at which flows the grid cells were flooded by more than half a foot to match the inundation data which was used above San Marcial in the FLO-2D model. This data was merged in a database with the URGOM gage flow data for the San Marcial gage for each alternative and year. The resulting data were then queried and summarized for each alternative and year from the southern end of the FLO-2D data (about San Marcial) down to the southern boundary of the study area.

Riparian Impact Analysis

Effects of changed river operations on riparian resources are generally indirect and long-term. Potential benefits and adverse impacts to Riparian resources were evaluated through several quantitative measures, described below.

<u>Acre-days of Spring Overbank Flooding:</u> This measure reflects the 40-year cumulative total spring seasonal (1 April through 1 July) acreage flooded times the duration of inundation in days. Riparian resources, particularly native riparian vegetation, respond well to spring flood flows. Long-term absence of adequate spring flood in riparian areas would gradually reduce recruitment and maintenance of existing vegetation and wildlife values.

<u>Frequency of Overbank Flooding:</u> This is measured as the percentage of days that a given reach or Section reaches the threshold discharge required to initiate overbank flooding in some areas. Adequate flood frequency for riparian resources is at least one year in five, or 20% for maintaining and regenerating native vegetation. Low frequency of overbank flooding in an area, despite the occasional large flood event, would decrease riparian ecosystem health and native vegetation.

<u>Mean Annual Maximum Acres of Overbank Flooding:</u> This is the 40-year mean of the highest annual acreage flooded within each river Section, measured in acres. The average extent of overbank flooding generally defines the area of riparian health, and a shrinking mean correlates to a shrinking riparian ecosystem.

<u>Average Annual Acre-days of Flooding in Vegetation Types:</u> This measures the hydrological support for various vegetation types in extent and duration. This is obtained by GIS overlay analysis of current vegetation mapping data with the data from FLO 2-D. Decreased surface hydrology within native and mixed vegetation types would produce long-term adverse impacts to vegetation and wildlife. It also creates conditions that favor the increase of exotic vegetation. [Figures 3.11, 3.12, and 3.14 detail these

data and will be referred back to throughout this Chapter's impact assessments; see Sections 3.3.1.1 Impact Analysis on Riparian Habitat; and 3.5.2.1 Impact Analysis on Terrestrial Riparian Fauna.]

Percentile of Inundation: This is a measure of the reliability of a particular area receiving overbank flows of moderate duration, supporting stable wetland function and ecological condition. Overbank flooding of existing wetland sites should remain in the range of the 25th and 75th percentile of the reach in which it is located.

Peak Flow Variability: We measured peak flow variability using the Coefficient of Variation, which is the ratio of the standard deviation of the 40-year time series of growing season peak flow (21 March through 31 October) compared to its mean. The larger the Coefficient of Variation, the greater the variability of the overbank discharge from one year to the next. Variability of flood flows would produce many beneficial effects to the riparian zone, while long-term low variability would result in adverse impacts.

Conservation Storage Capability: A measure of the Acre-Feet of water available in Abiquiu Reservoir that could be carried over and released for riparian purposes.

Peak-flow Augmentation Capability: A relative measure of the channel capacity below Abiquiu and below Cochiti. This provides the ability to deliver additional conservation storage and augment peak flows for riparian resources.

3.3.1.1 Impact Analysis on Riparian Habitat

Impacts of the No Action Alternative

The No Action alternative would continue operations largely unchanged, but with improved intra-agency coordination for flood control and delivery of water downstream. As modeled with no diversion into the LFCC, the current operations would provide the overall best support for riparian resources compared with all the action alternatives (**Figure L-3.10**). The current operations demonstrated support for existing wetlands, natural management areas, riparian fauna, and threatened and endangered species. Despite overall support of riparian resources, adverse impacts would occur in a No Action, varying in significance by river Section (**Table L-3.5**).

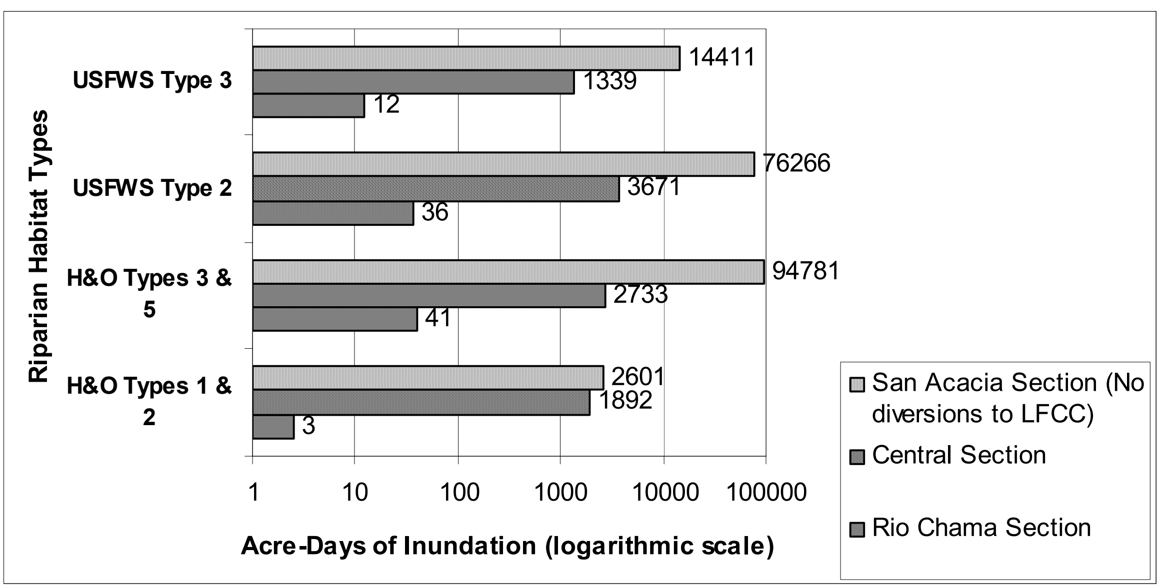


Figure L-3.10 Impacts of No Action with 0 diversions to the LFCC on inundation of riparian vegetation types, by section.

Table L-3.5 Impacts of No Action Alternative on Riparian Habitat Measures

Criteria	Measure	RIO CHAMA SECTION	CENTRAL SECTION	SAN ACACIA with 0 cfs Diversions to LFCC*	SAN ACACIA with 500 cfs Diversions to LFCC*	SAN ACACIA with 1,000 cfs Diversions to LFCC*	SAN ACACIA with 2,000 cfs Diversions to LFCC*
Supports regeneration of native vegetation	Acre-days of spring overbank flooding	1,137.0	7,646.0	132,065.0	Not modeled	Not modeled	Not modeled
Supports H&O vegetation classifications Type 1 and 2	Average annual acre-days in H&O Type 1 and 2	2.5	1,892.0	2,601.0	Not modeled	Not modeled	Not modeled
Supports H&O vegetation classifications Type 3 and 5	Average annual acre-days in H&O Type 3 and 5	40.6	2,733.0	94,781.0	Not modeled	Not modeled	Not modeled
Supports USFWS Resource Category 2	Average annual acre-days in USFWS — 2	36.0	3,671.0	76,266.0	Not modeled	Not modeled	Not modeled
Supports USFWS Resource Category 3	Average annual acre-days in USFWS — 3	12.0	1,339.0	14,411.0	Not modeled	Not modeled	Not modeled
Amount of Overbank Flooding	Mean annual maximum acres of overbank flooding	147.0	260.0	5,357.0	4,778.0	3,535.0	1,755.0
Frequency and Timing of overbank flooding	Percent years of spring overbank flooding	92.5	50.0	100.0	Not modeled	Not modeled	Not modeled

Rio Chama Section

Very little of the overall floodplain in the Rio Chama Section would receive overbank inundation according to the GIS analysis of acres of inundation shown in **Table L-3.5**. Though inundated acres would be flooded nearly 93% of the years included in the model, the area inundated is small, only 147 acres or 5% of the total vegetated acreage mapped. Under the No Action Alternative, the acre-days of spring overbank flooding would be very low, and flooding in mature cottonwood forest and valuable (USFWS 2) riparian habitats is very infrequent.

Figure L-3.11 shows that the No Action Alternative provides the lowest level of average annual days inundation in native vegetation among all alternatives. This result is especially significant in that native vegetation represents only 21% of the riparian forest in this section. Although cottonwood canopy forests can survive for many years without surface inundation, regeneration of these forests requires occasional flooding in open areas where native species can germinate. The No Action Alternative represents an adverse effect to native vegetation within the Rio Chama Section.

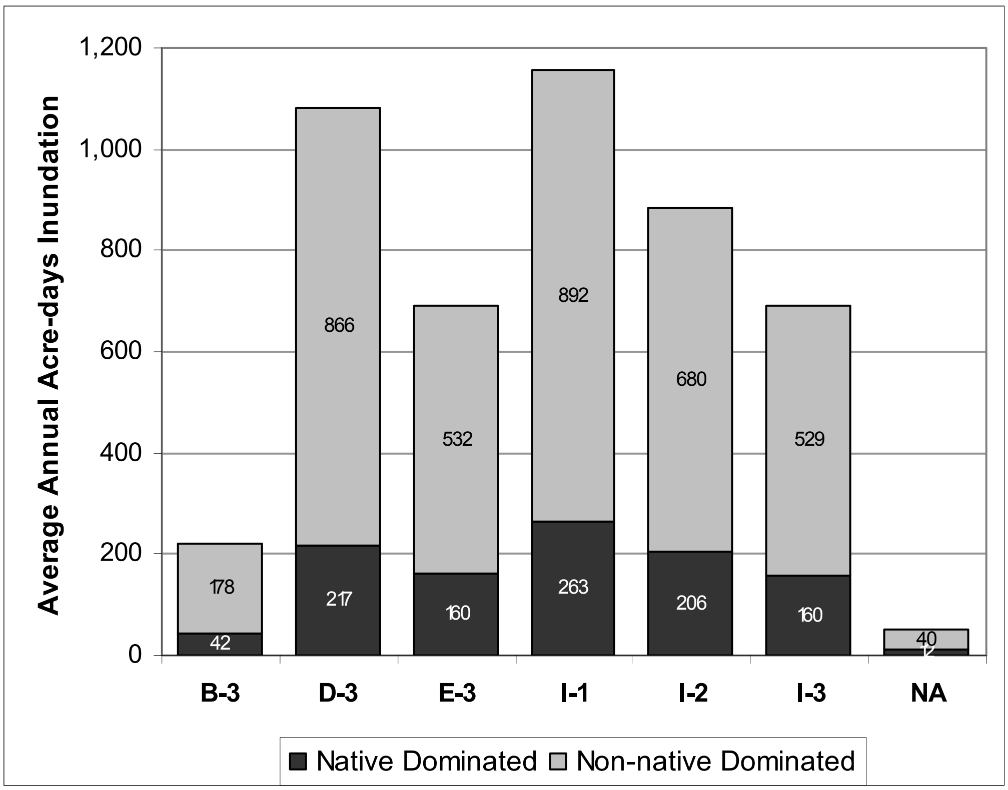


Figure L-3.11 Relative impacts of the alternatives on native vegetation communities in the Rio Chama Section, as total days of inundation. (χ^2=121.1, p= 0.000).

Central Section

Adverse impacts to riparian vegetation would continue to occur in the Central Section under the No Action Alternative (**Table L-3.5**). Since most facility operations remain unchanged in this alternative, negative trends in riparian ecosystem function of the Central Section identified in Chapter 3, such as lack of recruitment of native vegetation, and lack of sediment mobilization, would continue. The No Action Alternative provides some surface hydrological support to approximately 65% of the vegetated acres in the study area. Overbank flooding would occur somewhere in the Central Section in approximately half of the years, but with only 260 acres on average receiving these flood flows.

Evaluation of the relative impacts of No Action on native vegetation communities in the Central Section indicates that these valuable communities are inundated an average of 1,306 acre days per year, the fourth highest among all alternatives. The results of this analysis (**Figure L-3.12**) are significant, with a chi square of 280 and p=0.00. This indicates that the trends in vegetation change reported in Chapter 2 would continue under No Action, and would represent an adverse effect.

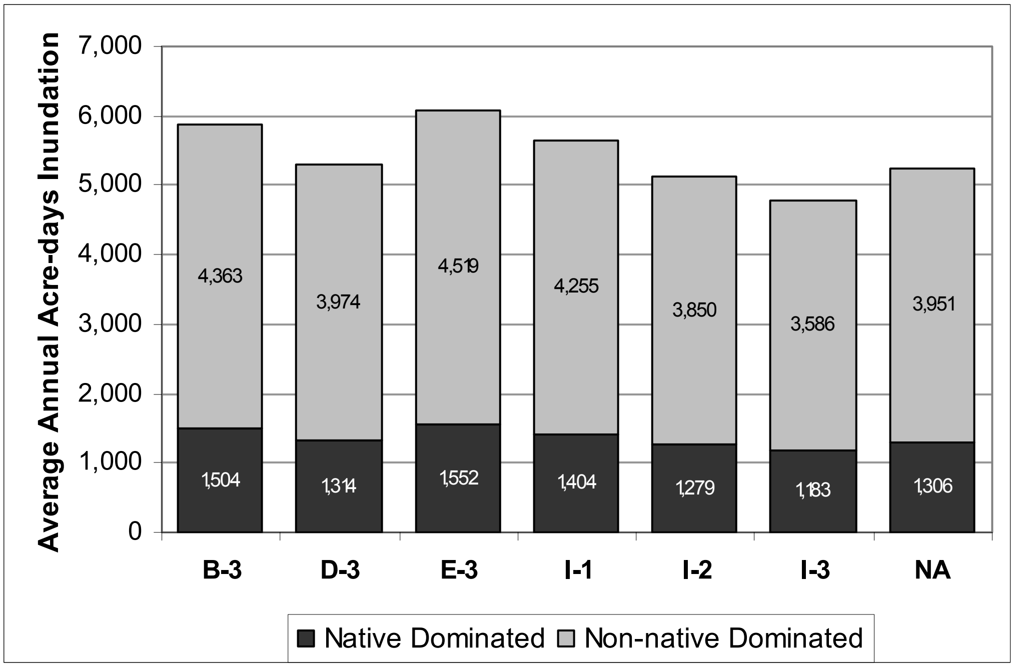


Figure L-3.12 Relative impacts of the alternatives on native vegetation communities in the Central Section, as total days of inundation. (χ^2=2,084.2, p= 0.000).

San Acacia Section

The No Action Alternative has variable effects according to the level of diversion of flows to the Low Flow Conveyance Channel (LFCC). Though a range of diversions from 0-2,000 cfs is authorized for the LFCC, no diversions have been made for two decades. A FLO-2D model was developed to determine the acres, duration, and frequency of overbank flooding in the San Acacia Section without diversions to the LFCC (0 cfs). The modeled data without diversions show that very little of the acre-days of inundation would occur in mature cottonwood forests (Hink & Ohmart Types 1 and 2), and that overall, very few acres are actually inundated, as shown in **Table L-3.5**. An average of 5,537 acres receive overbank flooding according to the FLO-2D model. However, those acres would receive flood flows in 100% of the modeled years, the highest frequency and area of overbank inundation in the entire study area. Inundation acres were not modeled for all possible diversions to the LFCC (Figure L-3.13). The highest value habitat types, USFWS Categories 2 and 3 would receive approximately 70% of the acre-days of inundation. Much of the San Acacia Section contains heavy and moderately infested forests dominated by saltcedar.

Spatial analysis was not completed for all possible diversions to the LFCC under No Action, making it impossible to compare the effects different diversions would have on native versus non-native vegetation, or on SWFL habitats, or other specific resources in the floodplain. Such effects would probably not be linear or easily predicted. Additional testing of spatial effects of variable diversions to the LFCC should the No Action with future diversions be selected.

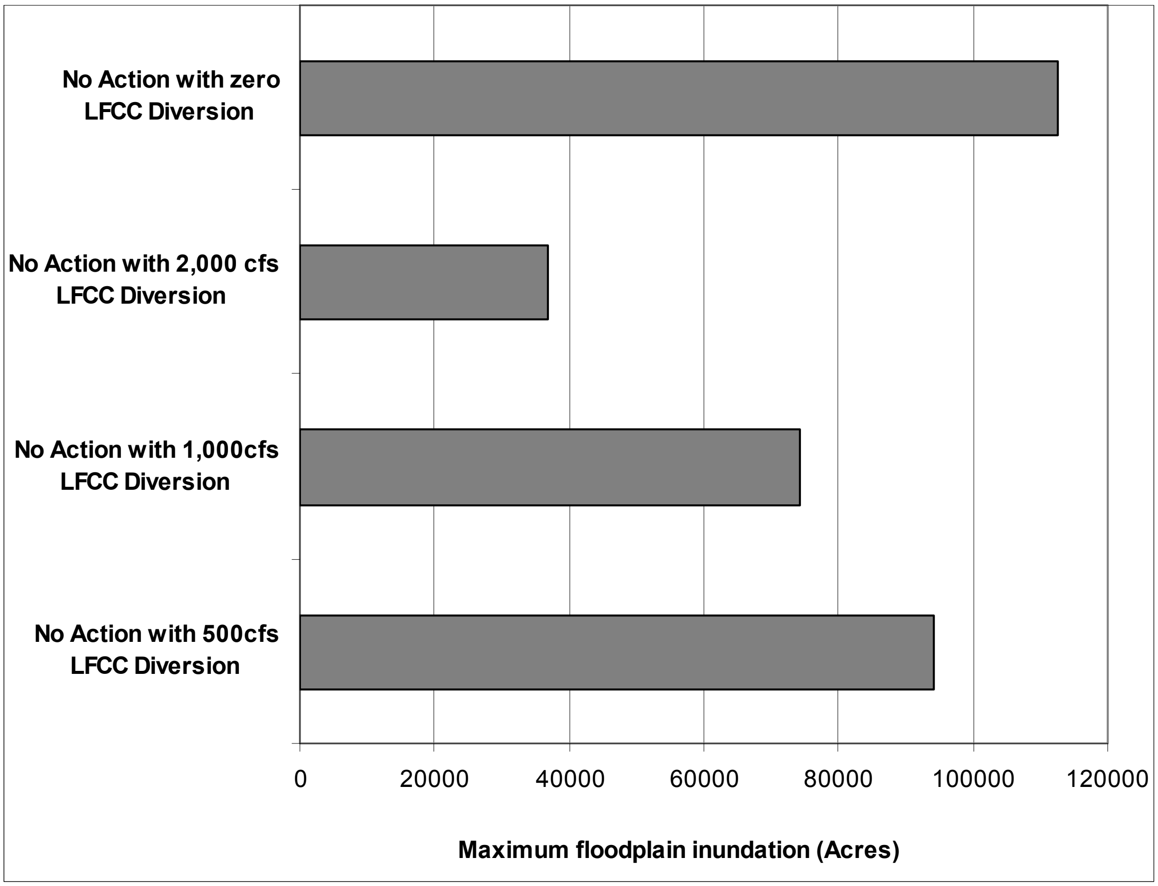


Figure L-3.13 Effects of variable diversions to Low Flow Conveyance Channel under No Action Alternative in maximum area floodplain iInundation in the San Acacia Section.

The San Acacia Section contains thousands of acres of non-native vegetation, with over 80% of the total acres of woody riparian vegetation dominated by saltcedar and other non-native species. The effects of inundation in native vegetation types was investigated and the results are shown in **Figure L-3.14**. This test shows that the No Action Alternative with zero diversions to the LFCC provides the greatest average annual acre-days of inundation in native vegetation communities compared with every action alternative. The chi-square goodness of fit test returned a value of 117,109, p=0.000, indicating high statistical significance. Decreasing overbank inundation by diverting water to the LFCC, even with other No Action operations, would probably result in significant decreases in inundation in native vegetation communities, and give a significantly adverse effect, as well. Further study of the spatial biological effects of diverting water to the LFCC is recommended should the No Action with future diversions be selected.

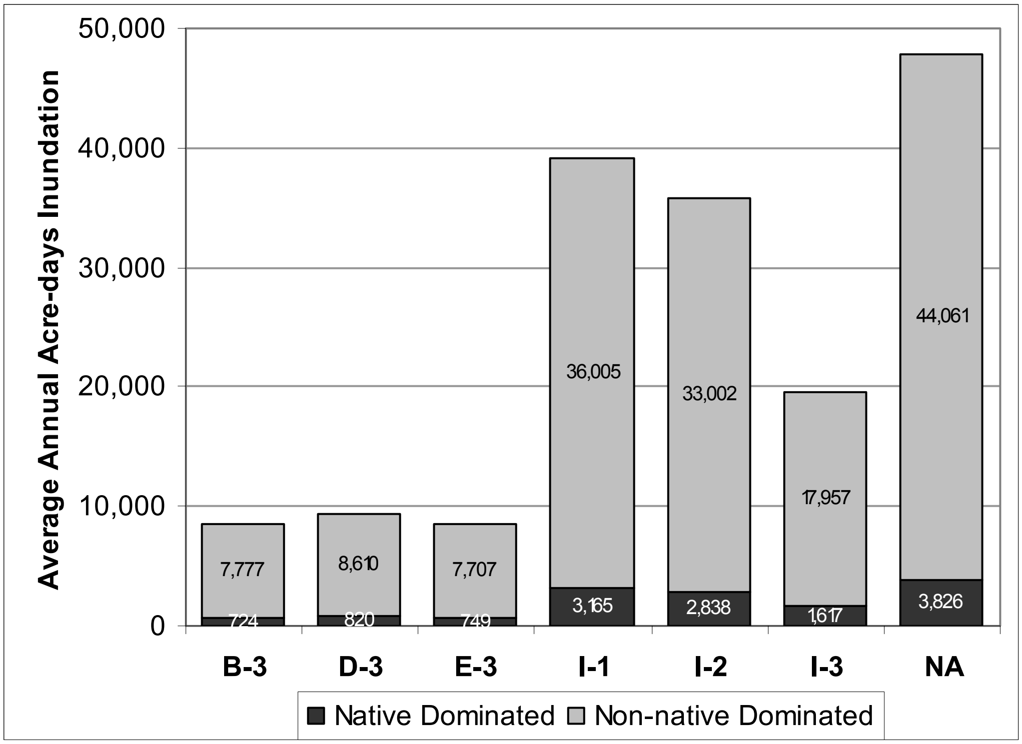


Figure L-3.14 Relative impacts of the alternatives on native vegetation communities in the San Acacia Section, as total days of inundation. (χ^2=14,791.4, p= 0.000).

Action Alternative B-3

Compared with the No Action Alternative, Alternative B-3 provides beneficial increases in inundation of valuable native vegetation types in the Rio Chama Section without resulting in the potentially adverse effects of prolonged or extensive overbank flooding (**Table L-3.6** and **Figure L-3.15**). In addition, this Alternative would result in a slight improvement in riparian support in the Central Section. Compared with No Action, Alternative B-3 results in moderate improvements in peak flow variability and average annual inundation in many valuable habitat types in the Rio Chama and Central Sections, including mature gallery cottonwood forests and in intermediate and young native forest types with dense understory, thereby benefiting avian species and other fauna (**Figure L-3.11**).

Alternative B-3 included carryover of up to 180,000 AF of native water at Abiquiu. An estimation was made of the potential benefit of partial use of carryover storage if it were used to augment peak flows and provide additional hydrological support for riparian habitats during prolonged dry periods. The results of this study (as shown in **Figure L-3.7)** show that the potential beneficial effect of carryover of native water storage at Abiquiu Reservoir ranks highest for Alternative B-3 among all alternatives. This alternative would completely offset modeled days of zero or less than 100 cfs flow in both the Central and San Acacia Sections.

Table L-3.6 Impacts of Alternative B-3 on Riparian Habitat Measures, Compared to No Action Alternative

Measure	RIO CHAMA SECTION	% Change Compared to No Action	CENTRAL SECTION	% Change Compared to No Action	SAN ACACIA SECTION	% Change Compared to No Action with Zero Diversions to LFCC*	% Change Compared to No Action with Equal Diversions to LFCC*
Acre-days of spring overbank flooding	1,070	-5.9%	8,429	10.2%	47,056	-64.4%	Not modeled
Average annual acre-days in H&O Type 1 and 2	6	156.0%	2,070	9.4%	510	-80.4%	Not modeled
Average annual acre-days in H&O Type 3 and 5	189	365.5%	3,088	13.0%	34,539	-63.6%	Not modeled
Average annual acre-days in USFWS — 2	158	338.9%	4,160	13.3%	33,550	-56.0%	Not modeled
Average annual acre-days in USFWS — 3	44	266.7%	1,449	8.2%	3,736	-74.1%	Not modeled
Mean annual maximum acres of overbank flooding	69	-53.1%	463	78.1%	1,294	-75.8%	-5.5%
Percent years of spring overbank flooding	85	-8.1%	48	-5.0%	90	-10.0%	Not modeled

Rio Chama Section

The area of inundation, or mean annual maximum acres of overbank flooding, in the Rio Chama section would decrease by over 50 percent, from 147 acres in the No Action Alternative to 69 acres in Alternative B-3. At the same time, the duration of inundation would increase substantially, providing better hydrological support, as shown in **Table L-3.6** and **Figure L-3.15**. Spring overbank flooding increases by 156% in Hink & Ohmart Types 1 and 2, the mature cottonwood forest. It also substantially improves the highest value vegetation type (USFWS Type 2) by approximately 339% when compared to the No Action Alternative. Other riparian habitats of intermediate height and young vegetation less than 15 feet tall (Hink & Ohmart Types 3 and 5), also show an increase of 365% in hydrological support. Since native vegetation dominates only a small proportion (21 percent) of Types 1, 3, and Type 5 vegetation in this section, the study examined the alternatives for impacts to hydrological support in vegetation dominated by native vegetation. The results for the Rio Chama (as shown in Figure L-3.11) show that Alternative B-3 would slightly increase the average annual acre-days of inundation in this valuable habitat. The increased inundation would benefit both exotic and native vegetation (**Figure L-3.15**).

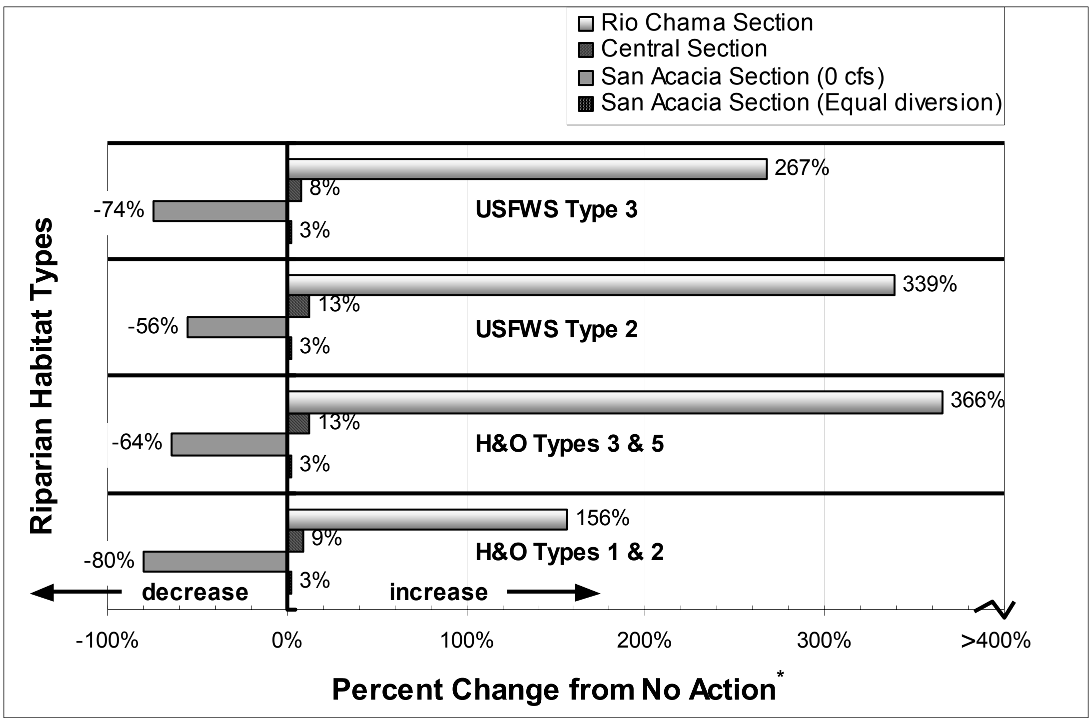


Figure L-3.15 Impact of Alternative B-3 on Riparian Habitat Support.
** No Action has variable diversions to LFCC, from 0 – 2,000 cfs*

Central Section

In the Central Section, Alternative B-3 would provide an overall improvement in many measures of riparian health, as shown in **Table L-3.6** and **Figure L-3.15**. The most significant increase would be a 78% projected increase in the maximum acres flooded in an average year, a change from 260 acres in No Action to a projected 463 acres in Alternative B-3. Increases in inundation would be felt disproportionately in lower value habitats with primarily non-native vegetation, but the mature cottonwood gallery forests (Hink and Ohmart Types 1 and 2) and the Intermediate forest types (Types 2 and 4) would have a 13% improvement in surface hydrology. Changes of less than 20% from the No Action Alternative are inside the margins of error for the study and therefore not significant, however. Improved surface hydrology in the Central Section would probably also result in slightly higher groundwater to support native forests in the area. **Figure L-3.12** showed that Alternative B-3 offers the second highest average annual acre-days of inundation for support of native vegetation in the Central Section.

San Acacia Section

Alternative B-3 would have an overall adverse effect on riparian vegetation in the San Acacia Section (**Table L-3.6** and **Figure L-3.15**). While the frequency of inundation would decrease only slightly (10 percent) compared to No Action, all other measures of riparian health would experience significant decreases of 50% to 80% compared to No Action. One of the most significant adverse effects would be felt in the mature cottonwood gallery forest (Hink and Ohmart Types 1 and 2). Spring inundation in these forest types would decrease by 80% over the No Action Alternative, according to the study. The overall areas of inundation would decrease from 5,334 acres in No Action to 1,294 acres in Alternative B-3. When compared to the No Action Alternative with similar 2,000 cfs diversions to the LFCC, the number of acres of inundation would be approximately the same. This indicated that, with Alternative B-3, the primary adverse effects in the San Acacia Section come from diversions to the LFCC, not the upstream operations proposed in the alternative.

Action Alternative D-3

Alternative D-3 included carryover of up to 180,000 AF of native water at Abiquiu. An estimation was made of the potential benefit of carryover storage if it were used to augment peak flows and provide additional hydrological support for riparian habitats during prolonged dry periods. The results of this study shows that the potential beneficial effect of carryover of native water storage in Abiquiu Reservoir is high in the Central Section, where both zero and less than 100 cfs flows days are fully covered. Use of carryover storage would not fully augment flows of less than 100 cfs in the San Acacia Section, however, but would cover approximately 90% of the shortfall (**Figure L-3.7**).

Rio Chama Section

The area of inundation, or mean annual maximum acres of overbank flooding, in the Rio Chama section, would decrease 8.8 percent, from 147 acres in the No Action Alternative to 134 acres in Alternative D-3. At the same time, the duration of inundation in native-dominated vegetation types would decrease a small amount, from approximately 92% to 85 percent, as shown in **Table L-3.7** and **Figure L-3.16**. It is the duration of overbank flooding that would produce the greatest effects with Alternative D-3 (as shown in **Figure L-3.11**). Spring overbank flooding increases by 1,180% in Hink & Ohmart Types 1 and 2, the mature cottonwood forest. It also substantially improves the highest value vegetation type (USFWS Type 2) by approximately 1,861% when compared to the No Action Alternative. Other riparian habitats of intermediate height and young vegetation less than 15 feet tall (Hink & Ohmart Types 3, 4, and 5), show an increase of over 2,000 acre-days of inundation, although these vegetation types are dominated by non-native vegetation.

Table L-3.7 Impacts of Alternative D-3 on Riparian Habitat Measures, Compared to No Action Alternative

Measure	RIO CHAMA SECTION	% Change Compared to No Action	CENTRAL SECTION	% Change Compared to No Action	SAN ACACIA SECTION	% Change Compared to No Action with Zero Diversions to LFCC*	% Change Compared to No Action with Equal Diversions to LFCC*
Acre-days of spring overbank flooding	2,643	132.5%	7,606	-0.5%	48,756	-63.1%	Not modeled

Measure	RIO CHAMA SECTION	% Change Compared to No Action	CENTRAL SECTION	% Change Compared to No Action	SAN ACACIA SECTION	% Change Compared to No Action with Zero Diversions to LFCC*	% Change Compared to No Action with Equal Diversions to LFCC*
Average annual acre-days in H&O Type 1 and 2	32	1,180%	1,875	-0.9%	546	-79.0%	Not modeled
Average annual acre-days in H&O Type 3 and 5	857	2,010.8%	2,771	1.4%	36,789	-61.2%	Not modeled
Average annual acre-days in USFWS — 2	706	1,861.1%	3,688	0.5%	34,159	-55.2%	Not modeled
Average annual acre-days in USFWS — 3	266	2,116.7%	1,345	0.4%	4,137	-71.3%	Not modeled
Mean annual maximum acres of overbank flooding	134	-8.8%	280	7.7%	1,233	-77.0%	-10.5%
Percent years of spring overbank flooding	85	-8.1%	48	-5.0%	90	-10.0%	Not modeled

Since native vegetation dominates only a small proportion (21 percent) of Types 1, 3, and Type 5 vegetation in this section, the study examined the alternatives for impacts to hydrological support in vegetation dominated by native vegetation. The results for the Rio Chama (**Figure L-3.11**) show that Alternative D-3 provides the second highest support for native vegetation types by increasing the average annual acre-days of inundation in this valuable habitat by over 200% compared to No Action. The increased acre-days of inundation would benefit both exotic Russian olive and native vegetation communities.

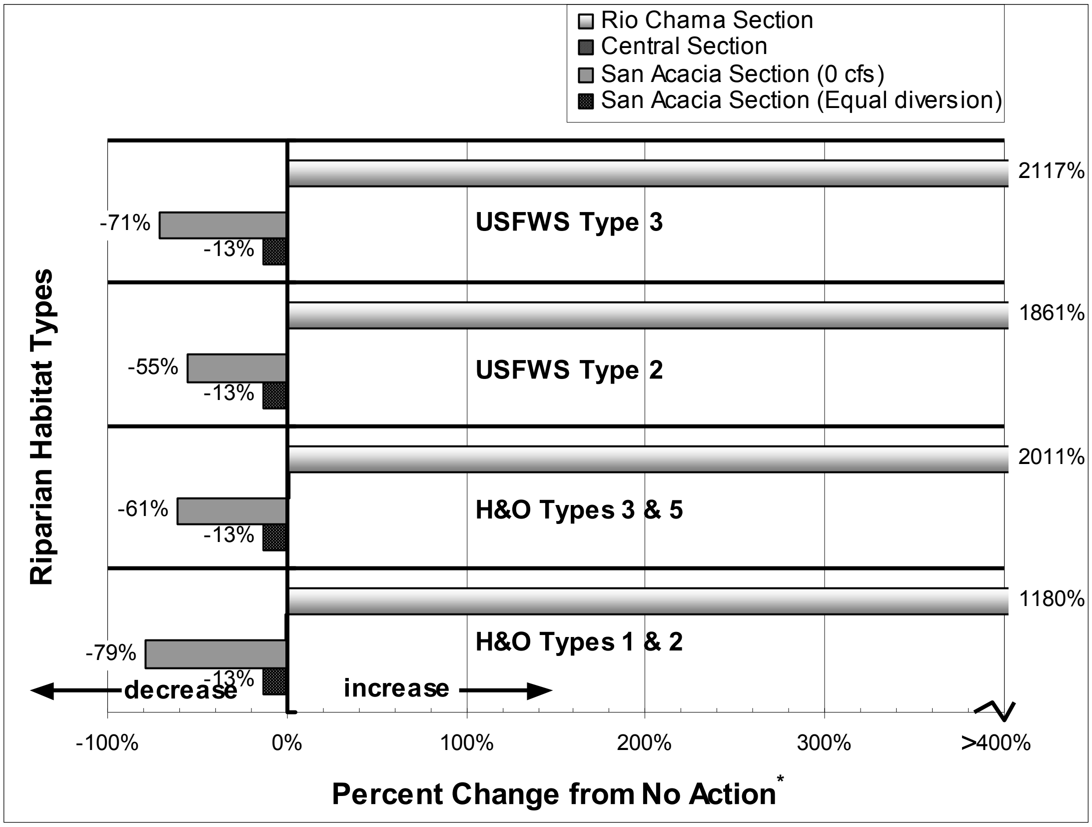


Figure L-3.16 Impact of Alternative D-3 (0 – 2,000 cfs diversion) on Riparian Habitat Support.
*** No Action has variable diversions to LFCC, from 0 – 2,000 cfs**

Central Section

In the Central Section, Alternative D-3 would provide virtually no change from the No Action Alternative in all measures of riparian health, including average annual acre-days of inundation in native vegetation. (**Figure L-3.12**).

San Acacia Section

Alternative D-3 would have an overall adverse effect on riparian vegetation in the San Acacia Section when compared with the No Action Alternative with zero diversions to the LFCC. While the frequency of inundation would decrease only slightly (10 percent) compared to No Action, all other measures of riparian health would experience significant decreases of 55% to 79 percent, as shown in **Table L-3.8** and Figure L-3.16. One of the most significant adverse effects would be felt in the mature cottonwood gallery forest (Hink and Ohmart Types 1 and 2). Spring inundation in these forest types would decrease from 2,601 acre-days in the No Action Alternative to 546 acre-days in D-3. However, when compared to the No Action Alternative with similar 2,000 cfs diversions to the LFCC, the number of acres of inundation would be approximately the same. This indicates that, with Alternative D-3, the primary adverse effects in the San Acacia Section come from diversions to the LFCC, rather than from the upstream operations proposed in the alternative. Alternative D-3 would significantly decrease support for native vegetation as well as decreasing inundation to non-native dominated communities (**Figure L-3.14**).

<u>Action Alternative E-3</u>

Alternative E-3 included carryover of up to 180,000 AF of native water at Abiquiu. An estimation was made of the potential benefit of partial use of carryover storage if it were used to augment peak flows and provide additional hydrological support for riparian habitats during prolonged dry periods. The results of this study shows that the potential beneficial effects of carryover of native water storage at Abiquiu Reservoir fully offsets any low- or zero-flow days in the Central Section. It also offsets about 90% of low flow days in the San Acacia Section (**Table L-3.8**and **Figure L-3.7**).

Table L-3.8 Impacts of Alternative E-3 on Riparian Habitat Measures, Compared to No Action Alternative

Measure	RIO CHAMA SECTION	% Change Compared to No Action	CENTRAL SECTION	% Change Compared to No Action	SAN ACACIA SECTION	% Change Compared to No Action with Zero Diversions to LFCC*	% Change Compared to No Action with Equal Diversions to LFCC*
Acre-days of spring overbank flooding	2,006	76.4%	8,733	14.2%	46,859	-64.5%	Not modeled
Average annual acre-days in H&O Type 1 and 2	22	780.0%	2,123	12.2%	542	-79.2%	Not modeled
Average annual acre-days in H&O Type 3 and 5	542	1,235.0%	3,209	17.4%	35,764	-62.3%	Not modeled
Average annual acre-days in USFWS — 2	470	1,205.6%	4,294	17.0%	33,585	-56.0%	Not modeled
Average annual acre-days in USFWS — 3	164	1,266.7%	1,499	11.9%	3,662	-74.6	Not modeled
Mean annual maximum acres of overbank flooding	108	-26.5%	496	90.8%	1,285	-76.0%	18%
Percent years of spring overbank	88	-5.4%	40	-20.0%	90	-10.0%	Not modeled

flooding							

Rio Chama Section

Alternative E-3 would decrease the mean annual maximum acres of overbank flooding in the Rio Chama Section from 147 acres in the No Action Alternative, to 108 acres. At the same time, the frequency of inundation would decrease a small amount, from approximately 92% to 88 percent (**Table L-3.8**). It is the duration of overbank flooding that would produce the greatest effects with Alternative E-3 (**Figure L-3.17**). Spring overbank flooding would increase by 780% in Hink & Ohmart Types 1 and 2, the mature cottonwood forest. E-3 also substantially improves the highest value vegetation type (USFWS Type 2) by approximately 1,205% when compared to the No Action Alternative. Other riparian habitats of intermediate height, and young vegetation less than 15 feet tall (Hink & Ohmart Types 3 and 5), show an increase of over 1,235 acre-days of inundation.

Since native vegetation dominates only a small proportion (21 percent) of Types 1, 3, and Type 5 vegetation in this section, the study examined the alternatives for impacts to hydrological support in vegetation dominated by native species. The results for the Rio Chama (**Figure L-3.17**) show that Alternative E-3 would have significant beneficial effects on native vegetation types by increasing the average annual acre-days of inundation in this valuable habitat compared to the No Action Alternative. The increased acre-days of inundation would benefit both exotic and native species and result in long-term improvement of native plant communities. However, this alternative shares a ranking of fourth with Alternative I-3 among all action alternatives.

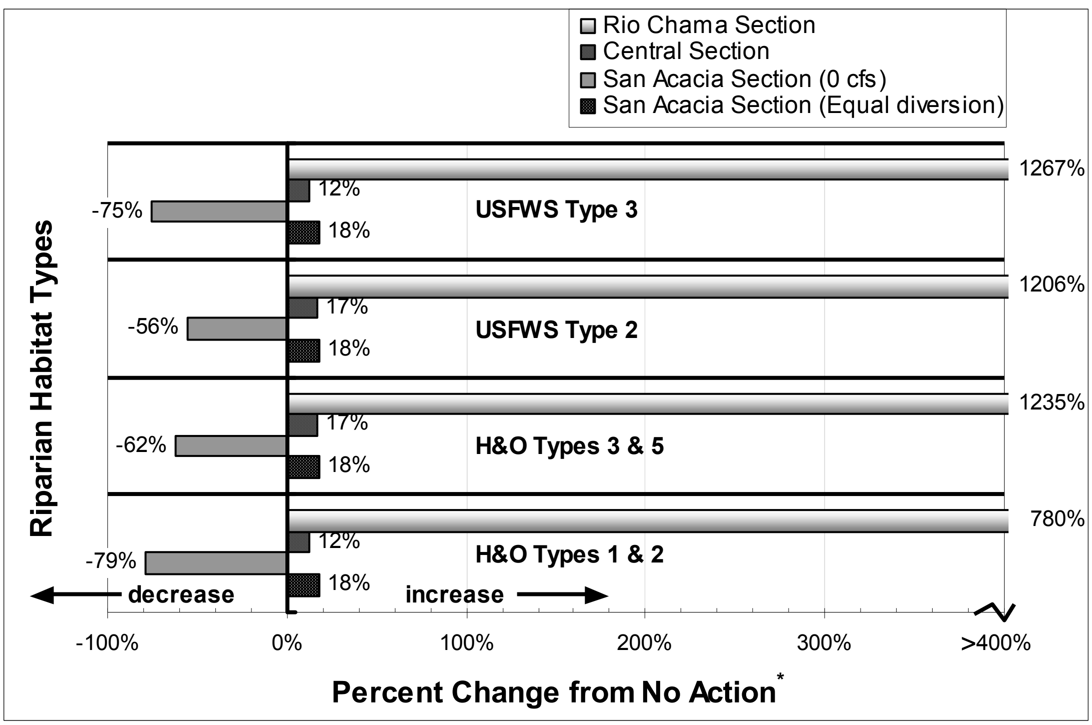


Figure L-3.17 Impact of Alternative E-3 (0 – 2,000 cfs diversion) on Riparian Habitat Support.
** No Action has variable diversions to LFCC, from 0 – 2,000 cfs*

Central Section

In the Central Section, Alternative E-3 would provide the highest support for native plant communities. However, the percent change from No Action is within our margin of error, so the alternative statistically provides virtually no change from the No Action Alternative in all measures of riparian health, as shown in **Table L-3.8**and **Figure L-3.17**. Since all measures of riparian health are less than 10% compared to No Action, and changes this small are inside the margins of error for the study, they would be undetectable.

San Acacia Section

Alternative E-3 would have an overall adverse effect on riparian vegetation in the San Acacia Section when compared with the No Action Alternative with zero diversions to the LFCC. While the frequency of inundation would decrease only slightly (10 percent) compared to No Action, all other measures of riparian health would experience significant decreases of 56% to 79 percent (**Figure L-3.17**). One of the most significant adverse effects would be felt in the mature cottonwood gallery forest (Hink and Ohmart Types 1 and 2). Spring inundation in these forest types would decrease from 2,601 acre-days in the No Action Alternative to 542 acre-days in E-3. However, when compared to the No Action Alternative with similar 2,000 cfs diversions to the LFCC, the number of acres of inundation would be 18% greater in E-3.

Action Alternative I-1

Alternative I-1 included carryover of up to 20,000 AF of native water at Abiquiu. An estimation was made of the potential benefit of partial use of carryover storage if it were used to augment peak flows and provide additional hydrological support for riparian habitats during prolonged dry periods. The results of this study shows that the use of carryover of native water storage in Abiquiu Reservoir under this Alternative provides coverage for zero-flow days in the Central Section, but does not supports the less than 100 cfs flows in Central Section. This Alternative also does not support the less than 100 cfs flows in San Acacia at any significant level (**Table L-3.9** and **Figure L-3.7**).

Rio Chama Section

Alternative I-1 would have a profound effect on the riparian vegetation of the Rio Chama Section. The percent of years and average acres receiving overbank flooding would remain the same in this alternative as in the No Action. **Figure L-3.10** and **Figure L-3.18** show that the duration of inundation would increase significantly, resulting in over 2,000% change from No Action. It is not clear if these increases in inundation duration would be beneficial to native species or if the duration would exceed the physiological ability of cottonwoods to grow with anoxic root conditions.

Since native vegetation dominates only a small proportion (21 percent) of Types 1, 3, and Type 5 vegetation in this section, the study examined the alternatives for impacts to hydrological support in vegetation dominated by native vegetation. The results for the Rio Chama (**Figure L-3.11**) show that Alternative E-3 would adversely affect native vegetation types significantly by reducing the total days of inundation in this valuable habitat compared to the No Action Alternative. The increased acre-days of inundation would benefit primarily exotic species and result in long-term loss of native plant communities.

Table L-3.9 Impacts of Alternative I-1 on Riparian Habitat Measures, Compared to No Action Alternative

Measure	RIO CHAMA SECTION	% Change Compared to No Action	CENTRAL SECTION	% Change Compared to No Action	SAN ACACIA SECTION	% Change Compared to No Action with Zero Diversions to LFCC*	% Change Compared to No Action with Equal Diversions to LFCC*
Acre-days of spring overbank flooding	3,004	164.2%	8,255	8.0%	111,901	-15.3%	Not modeled
Average annual acre-days in H&O Type 1 and 2	39	1,460.0%	2,050	8.4%	2,129	-18.1%	Not modeled
Average annual acre-days in H&O Type 3 and 5	902	2,121.7%	2,929	7.2%	80,685	-14.9%	Not modeled
Average annual acre-days in USFWS — 2	782	2,072.2%	3,959	7.8%	65,491	-14.1%	Not modeled
Average annual acre-days in USFWS — 3	272	2,166.7%	1,434	7.1%	12,156	-15.6%	Not modeled
Mean annual maximum acres of overbank flooding	147	0.0%	303	16.5%	2,601	-51.4%	-3%
Percent years of spring overbank flooding	93	0.0%	53	5.0%	95	-5.0%	Not modeled

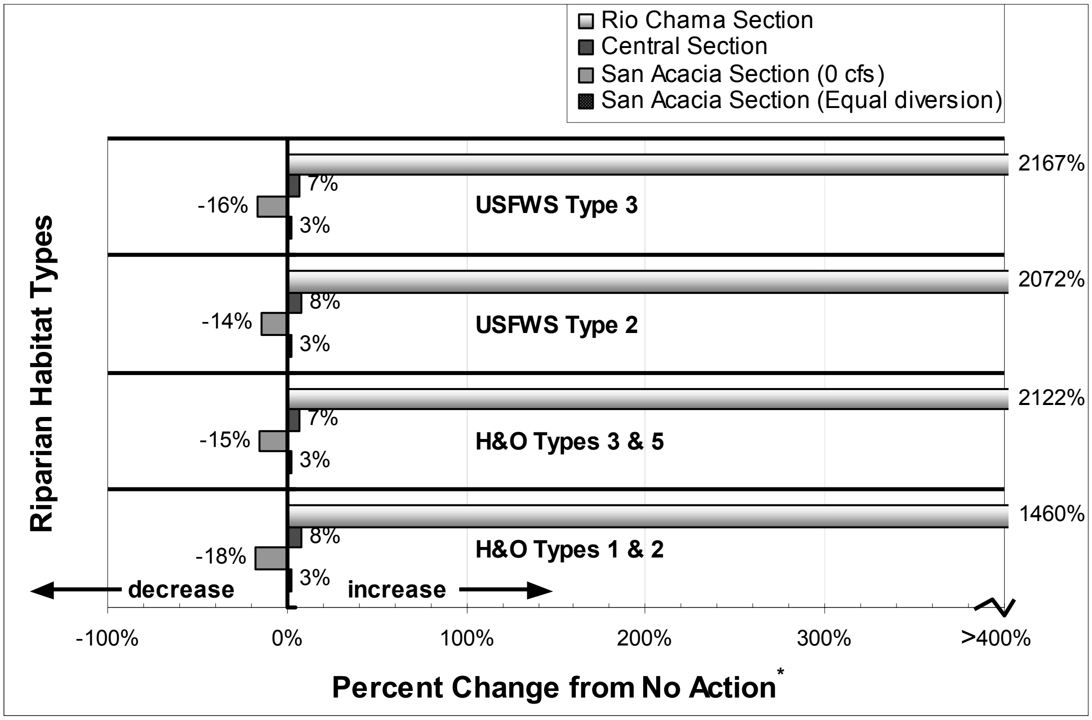


Figure L-3.18 Impact of Alternative I-1 (0 – 500 cfs diversion) on Riparian Habitat Support.
**** No Action has variable diversions to LFCC, from 0 – 2,000 cfs***

Central Section

In the Central Section, Alternative I-1 would produce slight increases in all measures of riparian health compared to No Action. This includes a 16% increase in mean annual maximum acres of overbank flooding and an increase in the frequency of overbank flooding. Improvements would be slight and would be in all valuable types of riparian vegetation in equal measure. The observed change is small, as shown in **Figure L-3.18**, but is consistent across all valuable riparian habitat measures.

San Acacia Section

Alternative I-1 would have a moderate adverse effect on the San Acacia Section, primarily in the reduced mean annual maximum acres of overbank flooding. This area of overbank flooding would decrease by 51% when compared to the No Action Alternative with zero diversions to the LFCC, as shown in **Table L-3.9** and **Figure L-3.18**. When compared to No Action with similar levels of diversion, in this case a cap of 500 cfs, Alternative I-1 is the same as the No Action Alternative. Decreased hydrological support of mature cottonwood forest types (Hink and Ohmart Types 1 and 2) and intermediate vegetation structures (Hink and Ohmart Types 3 and 4) would range from 15 to 18% when compared to No Action with zero diversions, levels that also fall inside the margins of error for the study and are therefore not significant.

<u>Action Alternative I-2</u>

Alternative I-2 included carryover of up to 75,000 AF of native water at Abiquiu. An estimation was made of the potential benefit of partial use of carryover storage if it were used to augment peak flows and provide additional hydrological support for riparian habitats during prolonged dry periods. The results of this study shows that the potential effects of carryover of native water storage at Abiquiu Reservoir is only somewhat supportive. Both zero- and less than 100 cfs- flows in the Central Section are fully covered under this alternative, but only about 60% of the less than 100 cfs flows are supported in the San Acacia Section (**Table L-3.10** and **Figure L-3.7**).

Table L-3.10 Impacts of Alternative I-2 on Riparian Habitat Measures, Compared to No Action Alternative

Measure	RIO CHAMA SECTION	% Change Compared to No Action	CENTRAL SECTION	% Change Compared to No Action	SAN ACACIA SECTION	% Change Compared to No Action with Zero Diversions to LFCC*	% Change Compared to No Action with Equal Diversions to LFCC*
Acre-days of spring overbank flooding	2,450	115.5%	7,424	-2.9%	91,773	-30.5%	Not modeled
Average annual acre-days in H&O Type 1 and 2	28	1,020.0%	1,827	-3.4%	1,861	-28.5%	Not modeled
Average annual acre-days in H&O Type 3 and 5	692	1,604.4%	2,678	-2.0%	65,443	-31.0%	Not modeled
Average annual acre-days in USFWS — 2	599	1,563.9%	3,575	-2.6%	50,871	-33.3%	Not modeled
Average annual acre-days in USFWS — 3	210	1,650.0%	1,307	-2.4%	10,814	-25.0%	Not modeled
Mean annual maximum acres of overbank flooding	125	-15.0%	268	3.1%	2,464	-54.0%	32%
Percent years of spring overbank flooding	90	-2.7%	50	0.0%	90	-10.0%	Not modeled

Rio Chama Section

Alternative I-2 would have a profound effect on the riparian vegetation of the Rio Chama Section. The percent of years and average acres receiving overbank flooding would decrease slightly, but not significantly compared to the margins of error for the study, as shown in **Table L-3.10** and **Figure L-3.19**. However, the duration of inundation would increase significantly, resulting in changes in acre-days of inundation of 115 percent, increased inundation of Hink and Ohmart Types 1 and 2 vegetation and Types 3 and 5 vegetation of 1,020% and 1,604 percent, respectively. Duration of the spring inundation would be beneficial to native species as long as it would not exceed the physiological ability of cottonwoods to grow with anoxic root conditions.

Since native vegetation dominates only a small proportion (21 percent) of Types 1, 3, and Type 5 vegetation in this section, the study examined the alternatives for impacts to hydrological support in vegetation dominated by native vegetation. The results for the Rio Chama (**Figure L-3.11**) show that Alternative I-2 would inundate native vegetation types with nearly the same number of total inundation days during the 40-year period of study. This would result in a neutral effect to this valuable habitat compared to the No Action Alternative. The slight increase in total acre-days of inundation would benefit both native and exotic plant communities in approximately the same way that the No Action does.

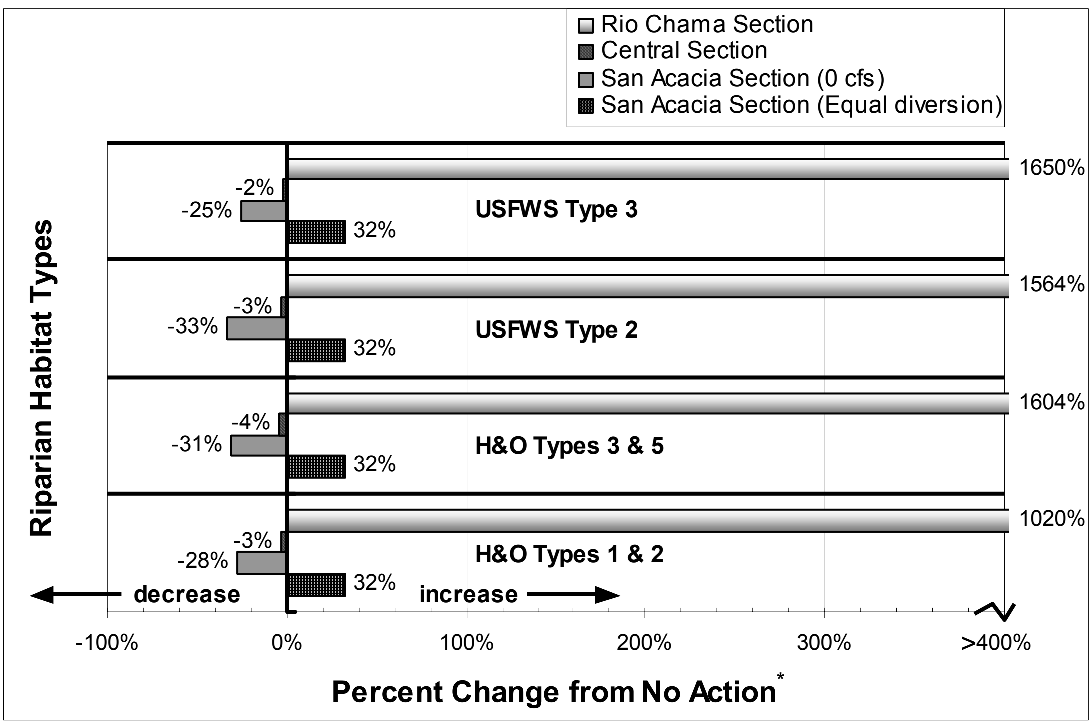


Figure L-3.19 Impact of Alternative I-2 (0 – 1,000 cfs diversion) on riparian habitat support.
** No Action has variable diversions to LFCC, from 0 – 2,000 cfs*

Central Section

In the Central Section, Alternative I-2 has a neutral effect on riparian habitats and is virtually indistinguishable from the No Action Alternative. No change would be anticipated for the Central Section riparian vegetation (**Table L-3.10** and **Figure L-3.19**). Current trends in vegetation would be expected to continue with this alternative.

San Acacia Section

Alternative I-2 would have an adverse effect on the San Acacia Section when compared to the No Action with zero diversions to the LFCC (**Figure L-3.19**). Decreased hydrological support (28 percent) of mature cottonwood forest of Hink and Ohmart Types 1 and 2, and 31% change in support of Hink and Ohmart Types 3 and 5 when compared to No Action with zero diversions, would be significant and adverse. This area of overbank flooding would decrease by 54 percent, and the acre-days of spring overbank flooding would decrease by over 30 percent. However, when compared to No Action with similar levels of diversion, in this case a cap of 1,000 cfs, Alternative I-2 would actually increase the mean annual maximum acres of inundation by 32 percent, and probably result in some general riparian improvements.

Action Alternative I-3

Alternative I-3 included carryover of up to 180,000 AF of native water at Abiquiu. An estimation was made of the potential benefit of partial use of carryover storage if it were used to augment peak flows and provide additional hydrological support for riparian habitats during prolonged dry periods. The results of this study shows that the potential beneficial effects of carryover of native water storage at Abiquiu Reservoir under Alternative I-3 ranks second among all alternatives. This alternative fully offsets any low- or zero-flow days in the Central Section. It also covers about 90% of low flow days in the San Acacia Section (**Table L-3.11** and **Figure L-3.7**).

Rio Chama Section

Alternative I-3 would probably result in improvements in riparian habitat in the Rio Chama, compared to the No Action (**Table L-3.11** and **Figure L-3.20**). The mean annual maximum acres of inundation would decrease slightly, from 147 to 108 acres, but the expected inundation in the most valuable habitat types would increase substantially, though not so much so that it would lead to declines. For example, the acre-days of inundation in Hink and Ohmart vegetation Types 1 and 2 would increase by 780 percent, an amount that would probably be well-tolerated by the mature cottonwood forests represented by these types. Support of Hink and Ohmart types 3 and 5 would increase by 1,227 percent, a level that would lead to habitat improvements. The percent of years receiving overbank flooding would decrease slightly, but not significantly compared to the margins of error for the study.

Since native vegetation dominates only a small proportion (30 percent) of Types 1, 3, and Type 5 vegetation in this section, the study examined the alternatives for impacts to hydrological support in vegetation dominated by native vegetation. The results for the Rio Chama (**Figure L-3.11**) show that Alternative E-3 would adversely affect native vegetation types significantly by reducing the total days of inundation in this valuable habitat compared to the No Action Alternative. The increased acre-days of inundation would benefit primarily exotic species and result in long-term loss of native plant communities.

Table L-3.11 Impacts of Alternative I-3 on Riparian Habitat Measures, Compared to No Action Alternative

Measure	RIO CHAMA SECTION	% Change Compared to No Action	CENTRAL SECTION	% Change Compared to No Action	SAN ACACIA SECTION	% Change Compared to No Action with Zero Diversions to LFCC*	% Change Compared to No Action with Equal Diversions to LFCC*
Acre-days of spring overbank flooding	2,073	82.3%	6,886	-9.9%	60,994	-53.8%	Not modeled
Average annual acre-days in H&O Type 1 and 2	22	780.0%	1,696	-10.4%	992	-61.9%	Not modeled
Average annual acre-days in H&O Type 3 and 5	539	1,227.6%	2,495	-8.7%	44,663	-52.9%	Not modeled
Average annual acre-days in USFWS — 2	467	1,197.2%	3,319	-9.6%	36,903	-51.6%	Not modeled
Average annual acre-days in USFWS — 3	163	1,258.3%	1,219	-9.0%	6,470	-55.1%	Not modeled
Mean annual maximum acres of overbank flooding	108	-26.5%	241	-7.3%	1,645	-69.3%	55%
Percent years of spring overbank flooding	88	-5.4%	48	-5.0%	90	-10.0%	Not modeled

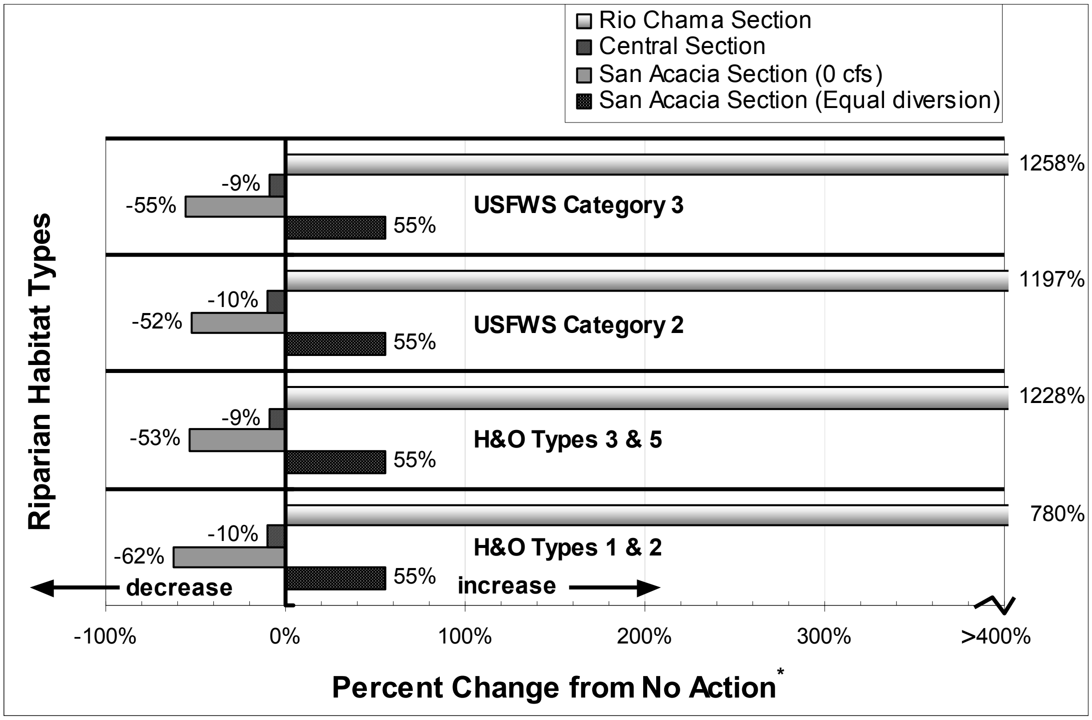


Figure L-3.20 Impact of Alternative I-3 (0 – 2,000 cfs diversion) on riparian habitat support.
** No Action has variable diversions to LFCC, from 0 – 2,000 cfs*

Central Section

In the Central Section, Alternative I-3 shows slight decreases in most measures of riparian health. As shown in **Table L-3.11**, most riparian measures would be approximately 5-10% less with this action alternative than with No Action. These changes are significant and adverse given the long-term trends of this river section. Current adverse trends in vegetation would be expected to continue with this alternative.

San Acacia Section

Alternative I-3 would have an adverse effect on the San Acacia Section when compared to the No Action with zero diversions to the LFCC (**Figure L-3.20**). Decreased hydrological support of mature cottonwood forest of Hink and Ohmart Types 1 and 2 of nearly 62% would be expected with this alternative. In addition, a 53% decrease in support of Hink and Ohmart Types 3 and 5 would be expected when compared to No Action with zero diversions. These changes would be significant and adverse. Overbank flooding in this area would decrease by 69% and the acre-days of spring overbank flooding would decrease by nearly 54 percent. However, when compared to No Action with similar levels of diversion, in this case a cap of 2,000 cfs, Alternative I-3 would actually increase the mean annual maximum acres of inundation by 55 percent.

<u>Impacts of Low Flow Conveyance Channel Diversions on Riparian Habitats in the San Acacia Section</u>

Variable diversions to the LFCC in the San Acacia Section contribute most of the modeled impacts of the No Action and Action Alternatives. **Figure L-3.21**demonstrates that all modeled alternatives with diversions above zero would decrease the overbank inundation in the San Acacia Section.

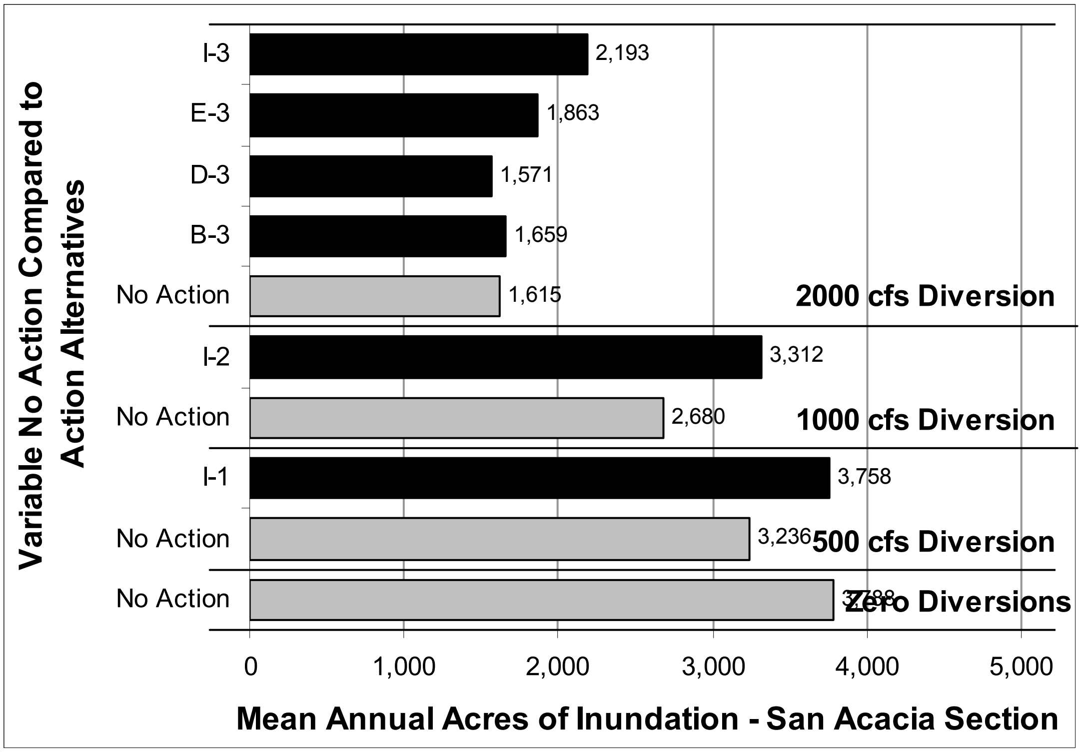


Figure L-3.21 Comparison of impacts from variable diversions to the LFCC in the San Acacia Section.

Varying the diversions to the LFCC among No Action alternatives is very linear (**Figure L-3.13**). The No Action Alternative does not have flexibility in the form of upstream storage and changed channel capacity to moderate flows, retain, or augment low flow years. The Action Alternatives show the effects of these additional flexibilities and can provide additional support to the San Acacia Section riparian resources. This support is shown in **Figure L-3.21**, which compares each action alternative to the No Action with equal diversions to the LFCC. As a result, all Action Alternatives except Alternative D-3 show relative improvements in overall hydrologic support to San Acacia Section vegetation (and associated wildlife) when compared to the No Action Alternative with similar diversions to the LFCC.

The No Action and I-1 or I-2, with diversion ranges of 0 to 1,000 cfs, provide around 3,000 mean annual acres of inundation to support riparian vegetation in this Section. At 2,000 cfs diversion to the LFCC, Alternatives D-3 and B-3 provide similar or lower hydrologic support than the No Action at 2,000 cfs, but only approximately 1,500 mean annual acres are impacted. Alternatives E-3 and I-3 show respectively higher levels of support than the No Action with inundation in approximately 2,000 mean annual acres.

Although most of the action alternatives moderate the adverse effects of diversions to the LFCC on riparian resources, they provide much lower support when compared to the No Action without diversions. Only Alternative I-1 and I-2 would provide overbank inundation sufficient to prevent long-term adverse effects to riparian vegetation, should the LFCC operations be implemented in the future. These two alternatives would also provide additional groundwater to riparian areas that occur between the river channel and the LFCC, supporting vegetation in these areas.

Impacts of the Alternatives on Native Vegetation within Each River Section

The amount of hydrological support for distinct vegetation classifications that would be provided by each action alternative was shown in **Figure L-3.15** through **Figure L-3.20**. The relative impacts of the alternatives on vegetation communities in each river Section (as total days of inundation), was detailed in

Figure L-3.11, **Figure L-3.12**, and **Figure L-3.14**. It has already been discussed that only 20% of the total mapped acres in all river sections combined are purely native stands. Native dominance ranges from 28% in the Rio Chama and 21% in the Central Section, to only 14% in San Acacia Section. Determining which alternative is most beneficial, *only* on the basis of total acres inundated, does not address the question of support for purely native vegetation.

Annual acres inundated under each action alternative were compared to the No Action to determine the percent change from current annual acres inundated (**Table L-3.12**). A chi-square goodness of fit analysis was performed to determine acre-days of inundation within all mapped acres (**Figure L-3.11**, **Figure L-3.12**, and **Figure L-3.14**). The chi-square residual was then used to determine how much of the average annual acre-days of inundation are actually supporting native vegetation as opposed to the 72- to 86-percent exotic acreage. Adjusted chi-square residuals <2 are not significant changes from No Action.

Rio Chama Section

The Rio Chama section currently supports the highest percentage of native-dominated vegetation (28 percent). There would be a significant increase in hydrological support of native species under all Action Alternatives. Alternative I-1 provides the best support in the Rio Chama with a +2,052% change from acres inundated under No Action (X^2=15,295 p=0.00). Alternative B-3 would provide the least support, but even this alternative shows a +247% improvement over the No Action Alternative.

Central Section

While only 21% of the Central Section is pure native vegetation, it contains the largest amount of desirable mature cottonwood gallery within the entire system studied. This river section requires the greatest hydrological support to inundate native communities. Examination of the chi-square analysis indicates that native acres inundated under Alternatives D-3 and I-2 do not vary significantly from the No Action. Alternative I-3 provides less support compared to No Action. All remaining action alternatives perform better than No Action, with Alternative E-3 showing the greatest improvement with a +19% change over No Action (X^2=96, p=0.00).

San Acacia Section

This section contains only 14% native-dominated vegetation communities. The remaining 86% is predominantly salt cedar. Examination of the chi-square analysis indicates that significant decreases in inundation of native vegetation would occur in all action alternatives Alternative B-3 is the poorest performer, with a –81% change from No Action. The best performer, Alternative I-1, is still at a significant –17% change from No Action (X^2=8,995 p=0.00).

Table L-3.12 Hydrological Support for Native Dominated Vegetation under Each Alternative

Alternative	No Action Native Annual Acres Inundated	Native Annual Acres Inundated	Percent Change from No Action
RIO CHAMA SECTION			
Alt B-3	12	42	246.5%
Alt D-3	12	217	1678.1%
Alt E-3	12	160	1212.6%
Alt I-1	12	263	2052.0%
Alt I-2	12	206	1582.7%
Alt I-3	12	160	1207.5%
CENTRAL SECTION			
Alt B-3	1,306	1,504	15.2%
Alt D-3	1,306	1,314	0.6%
Alt E-3	1,306	1,552	18.8%
Alt I-1	1,306	1,404	7.5%
Alt I-2	1,306	1,279	-2.1%
Alt I-3	1,306	1,183	-9.4%
SAN ACACIA SECTION			

Alternative	No Action Native Annual Acres Inundated	Native Annual Acres Inundated	Percent Change from No Action
Alt B-3	3,826	724	-81.1%
Alt D-3	3,826	820	-78.6%
Alt E-3	3,826	749	-80.4%
Alt I-1	3,826	3165	-17.3%
Alt I-2	3,826	2838	-25.8%
Alt I-3	3,826	1617	-57.7%

3.4 *Wetland Resources and Designated and Natural Management Areas*

3.4.1 *Measures of Impacts on Wetlands and Designated and Natural Management Areas*

Discharge Duration—These measures assess wetland habitat impacts by the change in duration of the 25th- and 75th-percentile flows of the No Action condition. The elevation of the water table in wetlands within the floodway correlates with the surface water elevation in the channel. The duration of low flows (less than the 25th percentile) is a measure of the capability of river flow to maintain minimum ground water levels in adjacent wetland. The duration of high flows (greater than the 75th percentile) is an indicator of inundation frequency of wetlands located on islands and in the overbank area. The duration of high flows also contributes to groundwater recharge and the stability of groundwater elevations.

Summary Data—Discharge frequencies were calculated from average monthly discharge data from URGWOM. The period of analysis included all 40 years of each model run but was limited to April 1 through September 30, an approximation of the regional growing season. **Table L-3.13** gives the 25th- and 75th-percentile flows at selected gauges in each river section under the No Action alternative. The No Action alternative in the San Acacia Section includes consideration of 0, 500, 1,000, and 2,000 cfs discharges to the LFCC. The 25^{th} and 75^{th} percentile flows shown for varying discharges to the LFCC are flows remaining in the river following diversion to the LFCC. Comparison of impacts from alternatives in this section requires comparison against a similar level of discharge to the LFCC.

Average Annual Acre-days of Inundation Data
Designated wildlife management areas are found throughout the Project's watershed (**Table L-2.17**), and all require groundwater support. Their mission statements range from Alamosa National Wildlife Refuge's purpose, "to support wetland and wildlife habitat" (Reach 1); the Belen State Waterfowl Area which provides forage and resting habitat to waterfowl (Reach 11); to the Bosque del Apache National Wildlife Refuge which has created 7,000 acres of wetlands vital to wildlife habitat (Reach 14). Representative wetland vegetation includes cattail marshes and the saltgrass meadows found in emerging wetlands. Hydrologic support of wetland areas would, by default, generally support Hink and Ohmart's categories of marsh or saltgrass meadow. Therefore, average annual acre-days of inundation in marsh and meadow habitats is used herein as a surrogate for support of Designated and Natural Management Areas.

3.4.1.1 Impact Analysis on Wetlands and Designated and Natural Management Areas

The duration (days) of flows that were less-than or greater-than these reference flows were calculated for all other action alternatives, by river section (**Table L-3.13** and **Table L-3.14**). Because the Rio Chama section is influenced by flow from two discrete drainages, durations calculated at the Chamita and Otowi gauges were averaged to characterize this section. The Chamita gage contributes about one third of the total flow at Otowi.

Table L-3.13 River Flows for the No Action Alternative at Selected Frequencies (April – September)

Section	Gauge	25th-percentile flow (cfs)	75th-percentile flow (cfs)
Rio Chama Section	Chamita	394	1095
Rio Chama Section	Otowi	867	2343
Central Section	Central Ave.	360	1908
San Acacia Section	San Acacia		
LFCC = 0 cfs		41	1756
LFCC = 500 cfs		104	1233
LFCC = 1,000 cfs		128	733
LFCC = 2,000 cfs		128	250

Table L-3.14 Duration (Days) with Flow Less than the 25th-Percentile Discharge of No-Action Hydrograph.
Values in Parentheses are the Percent Change from the No-Action Duration

Section	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Rio Chama Section							
Rio Chama-Chamita	1830	2074 (+13%)	1952 (+7%)	2013 (+10%)	1983 (+8%)	1922 (+5%)	2013 (+10%)
Rio Chama – Otowi	1830	1922 (+5%)	1891 (+3%)	1891 (+3%)	1891 (+3%)	1922 (+5%)	1891 (+3%)
Central Section	1830	1853 (+1%)	1845 (+1%)	1835 (0%)	1875 (+2%)	1877 (+3%)	1853 (+1%)
San Acacia Section							
LFCC = 500 cfs	1830				1854 (+1%)		
LFCC = 1,000 cfs	1830					1852 (+1%)	
LFCC = 2,000 cfs	1830	1827 (0%)	1859 (+2%)	1840 (+1%)			1851 (+1%)
Mean	1830	1884 (+3%)	1872 (+2%)	1869 (+2%)	1883 (+3%)	1884 (+3%)	1878 (+3%)
Proportion of No Action duration	1.00	0.97	0.98	0.98	0.97	0.97	0.97

Table L-3.13 summarizes the duration of flows less than the 25th-percentile flow and the percent change from the No Action duration at the reference flow. Durations that are appreciably greater than those of the No Action alternative indicate that river flows are lower for a longer period and may adversely affect the minimum ground water level in wetlands adjacent to the river channel. Generally, durations differed significantly (>10 percent) from the No Action alternative only in the Rio Chama Section for alternatives B-3, E-3, and I-3. This difference is largely attributed to the combined effects of Heron Reservoir waivers, native conservation water storage at Abiquiu Reservoir and changes in below Abiquiu channel capacities. Below the confluence of the Rio Chama with the Rio Grande with flows measured at Otowi gage, flow differences decrease to less than five percent, dampened by the two-thirds greater flow volume along the mainstem of the Rio Grande.

The proportional difference from the No Action duration was used to evaluate the alternatives, with a greater duration of low flows being the less desired condition. The Rio Chama section score weighted the Chamita gage equal to one-third, the Otowi gage equal to two-thirds based on proportion of flow. Thereafter, each section was weighted equally to determine the index value in the Decision Matrix.

Overall, there was no significant difference in duration of days with flows less than 25% of those expected under No Action.

Table L-3.15 summarizes the duration of flows greater than the 75th-percentile flow, and the percent change from the No Action duration at the reference flow. Durations that are significantly less than those of the No Action alternative indicate that river flows are less likely to inundate wetlands within the floodway.

Upstream storage appears to have the greatest impact on 75th-percentile flows along the Rio Chama, with alternatives B-3, D-3, E-3, and I-3 all showing decreases in duration of higher flows ranging from 37 to 39 percent. Alternatives I-2 and I-1 show proportionately lesser impacts of storage due to limitations on storage capacity imposed by the alternative. These proportional differences are dampened by the time the Rio Chama flows into the Rio Grande. The 75th percentile flows decrease only by 12% for alternatives D-3, E-3, and I-3. The 75th percentile flows at Otowi are higher than expected for alternative B-3, probably due to a higher duration of high flow days due to the lesser channel capacity below Abiquiu allowed under this alternative. Changes in 75th percentile flows at Otowi are insignificant for alternatives I-1 and I-2. Changes in 75th percentile flows in the Central Section are similar to those observed at Otowi with the exceptions of alternatives B-3 and E-3, which offer higher channel capacities below Cochiti. Flows among alternatives for the San Acacia section were compared to the corresponding LFCC diversion for no action. Typically, alternatives with higher upstream storage and higher channel capacities offered 13 to 18% greater durations of higher flow days. There were no significant differences in 75th-percentile flows at San Acacia under alternatives I-1 and I-2.

The proportional difference from the No Action duration was used to evaluate the alternatives, with a greater duration of higher flows being the desired condition. The Rio Chama section score weighted the Chamita gage equal to one-third, the Otowi gage equal to two-thirds based on proportion of flow. Thereafter, each section was weighted equally to determine the index value in the Decision Matrix. All alternatives were within 6% of the higher flow durations expected under No Action. Despite the slightly lesser performance in duration of 75th percentile flows under alternative E-3, this alternative offers the maximum peak flows attained in the San Acacia and Central sections as compared to any other alternative due to the increased channel capacity below Cochiti.

Table L-3.15 Duration (Days) with Flow Greater than 75th-Percentile Flow for the No Action Hydrograph. Values in Parentheses are the Percent Change From the No Action Duration

Section	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Rio Chama Section Rio Chama-Chamita Rio Grande - Otowi	1830 1830	1129 (-38%) 1739 (-5%)	1129 (-38%) 1617 (-12%)	1129 (-38%) 1617 (-12%)	1769 (-3%) 1800 (-2%)	1464 (-20%) 1769 (-3%)	1159 (-37%) 1617 (-12%)
Central Section	1830	1647 (-9%)	1586 (-13%)	1556 (-15%)	1769 (-3%)	1739 (-5%)	1617 (-12%)
San Acacia Section LFCC = 0 cfs LFCC = 500 cfs LFCC = 1,000 cfs LFCC = 2,000 cfs	1830 1830 1830 1830	2074 (+13%)	2166 (+18%)	2166 (+18%)	1830 (0%)	1891 (+3%)	2166 (+18%)
Mean	1830	1753(-4%)	1736 (-5%)	1726 (-6%)	1796 (-2%)	1766 (-3%)	1750 (-4%)
Proportion of No Action duration	1.00	0.96	0.95	0.94	0.98	0.97	0.96

<u>**No Action**</u>

The No Action alternative would continue operations largely unchanged, but would allow for diversions up to 2,000 cfs in the LFCC, with improved intra-agency coordination for flood control and delivery of water downstream. The No Action alternative best supports wetlands in the Rio Chama and Central sections because it provides the highest river flows and stores the least water in upstream reservoirs. As shown in the groundwater elevation maps along the San Acacia Section (**Figure L-3.22** to **Figure L-3.28**), active diversions to the LFCC under No Action better support wetland resources west of the Rio Grande and adjacent to the LFCC because they support higher and more stable groundwater elevations and increase the areal extent of high water table conditions during the April 1 to September 30 period. LFCC diversions greater than 1,000 cfs cause groundwater elevations to decrease and result in steeper groundwater elevation declines east of the Rio Grande. Operation of the LFCC has the potential to shift the extent and location of wetland resources supported, especially in the southern areas of the section near Fort Craig.

As shown on **Figure L-3.29** (GIS-based analysis), the areal extent of wetlands is anticipated to be maximal under LFCC diversions near 1,000 cfs. This level of diversion supports approximately 16,500 acres of wetlands along the east side of the river as well as adjacent to the LFCC structure. Zero diversion to the LFCC supports about 14,500 acres, but does not support wetlands on the west side of the river. The 2,000 cfs diversions to the LFCC support about 13,100 acres of wetlands, but draws water away from wetlands east of the river.

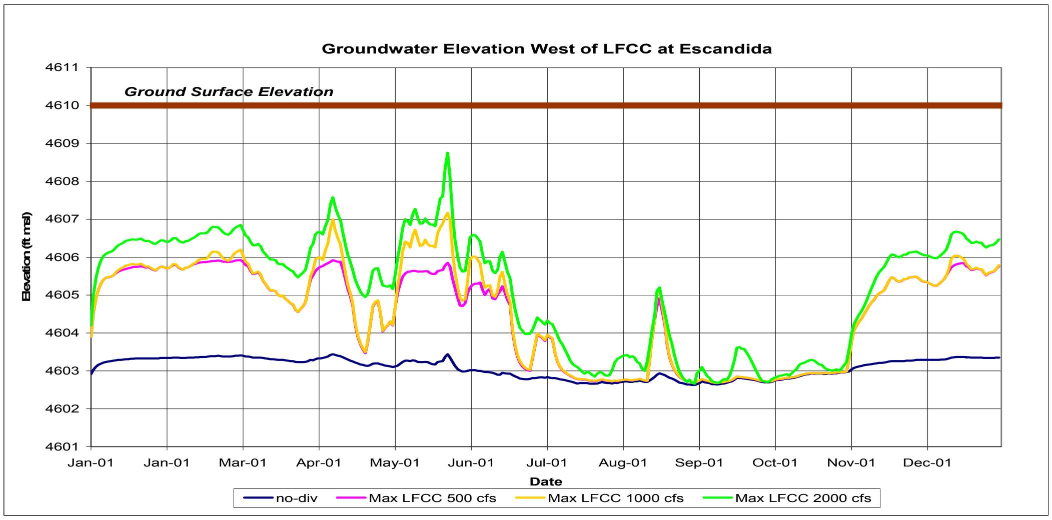


Figure L-3.22 Modeled seasonal groundwater elevations at a cross-section west of LFCC at Escondida with variable LFCC diversions.

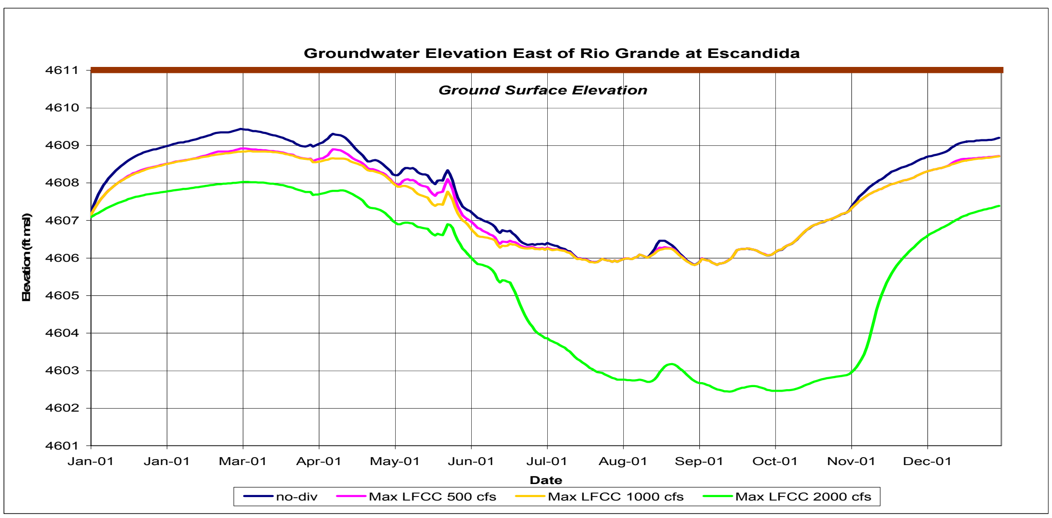


Figure L-3.23 Modeled seasonal groundwater elevations at a cross-section east of the Rio Grande at Escondida with variable LFCC diversions.

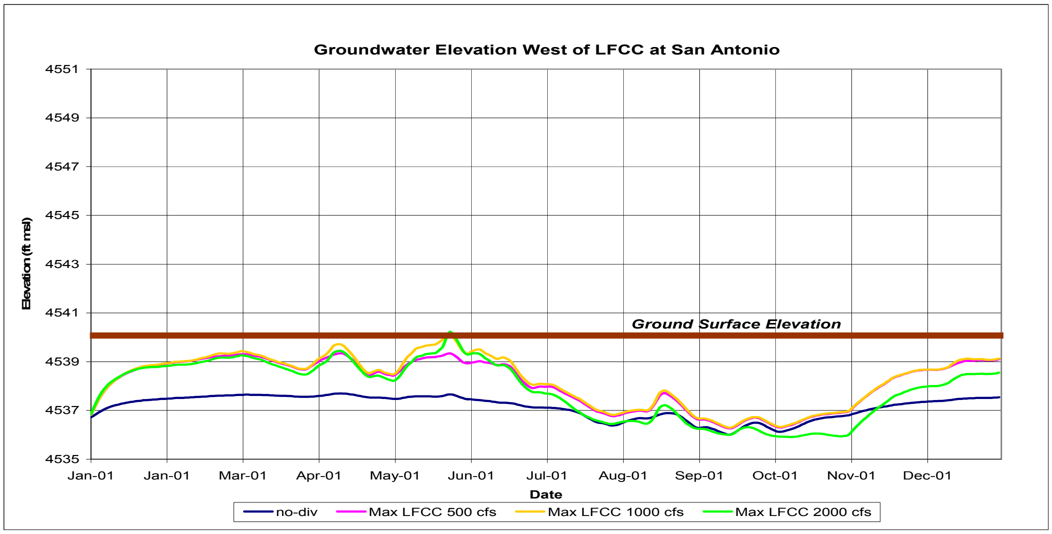


Figure L-3.24 Modeled seasonal groundwater elevations at a cross-section west of LFCC at San Antonio, New Mexico, with variable LFCC diversions.

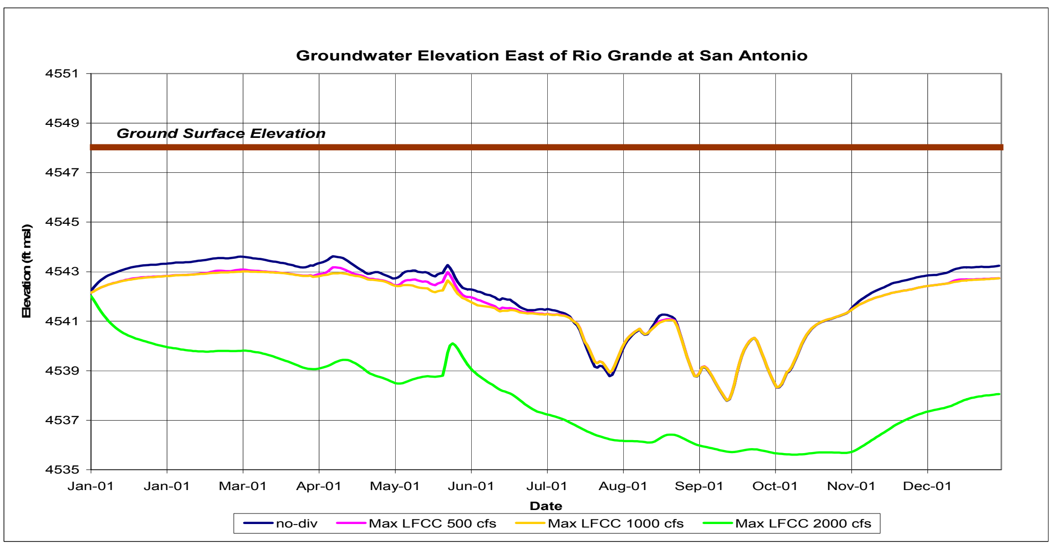


Figure L-3.25 Modeled seasonal groundwater elevations at a cross-section east of the Rio Grande at San Antonio, New Mexico, with variable LFCC diversions.

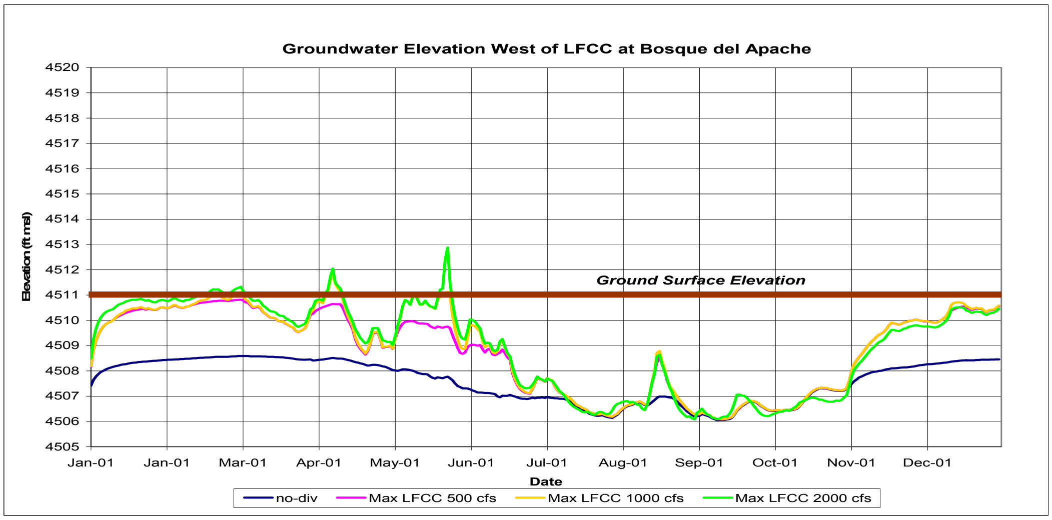


Figure L-3.26 Modeled seasonal groundwater elevations at a cross-section west of the LFCC at Bosque del Apache NWR, with variable LFCC diversions.

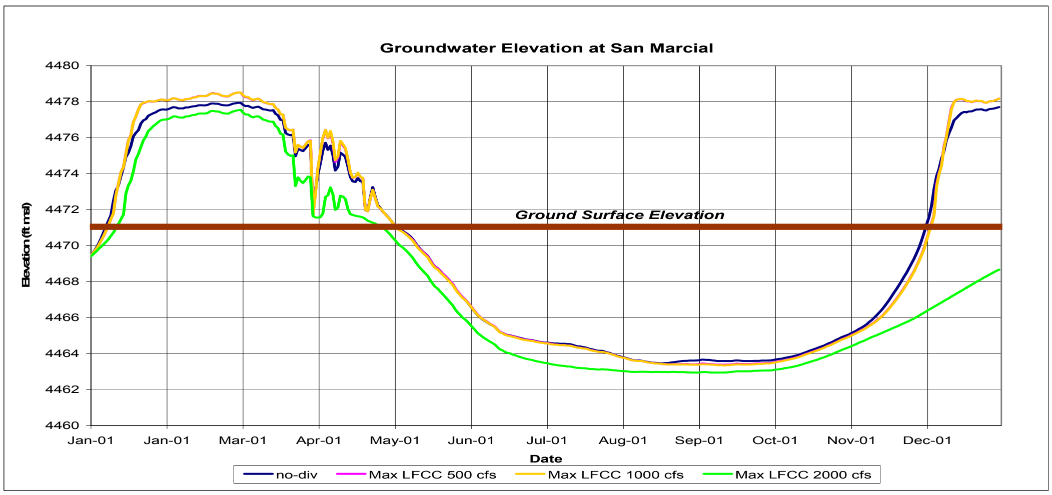


Figure L-3.27 Modeled seasonal groundwater elevations at a cross-section west of the LFCC at San Marcial, with variable LFCC diversions.

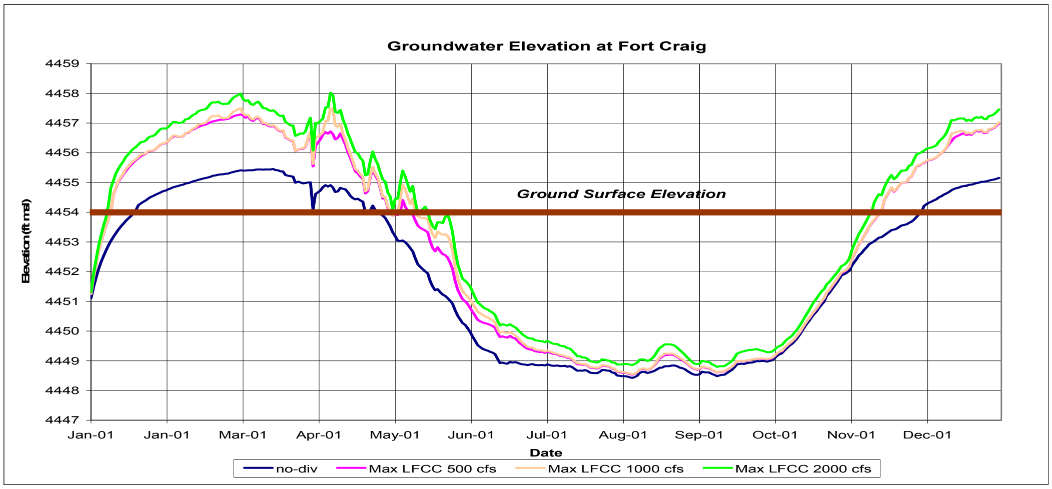


Figure L-3.28 Modeled seasonal groundwater elevations at a cross-section west of the LFCC at Fort Craig, with variable LFCC diversions.

Action Alternatives B-3, D-3, E-3 and I-3

These four alternatives showed very similar effects in both trend and magnitude in the three affected river sections. Features in common among these four alternatives include up to 180,000 acre-feet of annual storage at Abiquiu Reservoir and up to 2,000 cfs diversion to the Low-Flow Conveyance Channel. The four alternatives differed in terms of Heron waiver dates and channel capacities below Abiquiu and Cochiti dams. Alternatives with increases in channel capacity typically had increased peak flows and 75th percentile flows at gages within and downstream of the channel section with the higher capacity. Performance of these alternatives was compared to performance under No Action with 2,000 cfs diversions to the LFCC.

Low Flow Duration

Each of the four alternatives exhibited small (+3% to +4 percent) increases in the duration of low (less than the 25th percentile) flows. These slight changes in discharge duration would not appreciably affect the minimum ground water levels in wetlands within the floodway.

In both the Central and San Acacia sections, changes in low-flow duration were negligible (0% to +4 percent) among the four action alternatives. In the Rio Chama section however, the duration of low flows increased from 8% to 10% among these alternatives. While this is greater than changes in the other sections, this increase does not quite reach the threshold for a significant impact (10 percent). The storage of native water at Abiquiu Reservoir is the activity that most likely explains the observed increase in low-flow durations in the Rio Chama section; Rio Grande mainstem flows dampen these effects as observed in data from the Otowi gage, extending downstream to the Central and San Acacia sections.

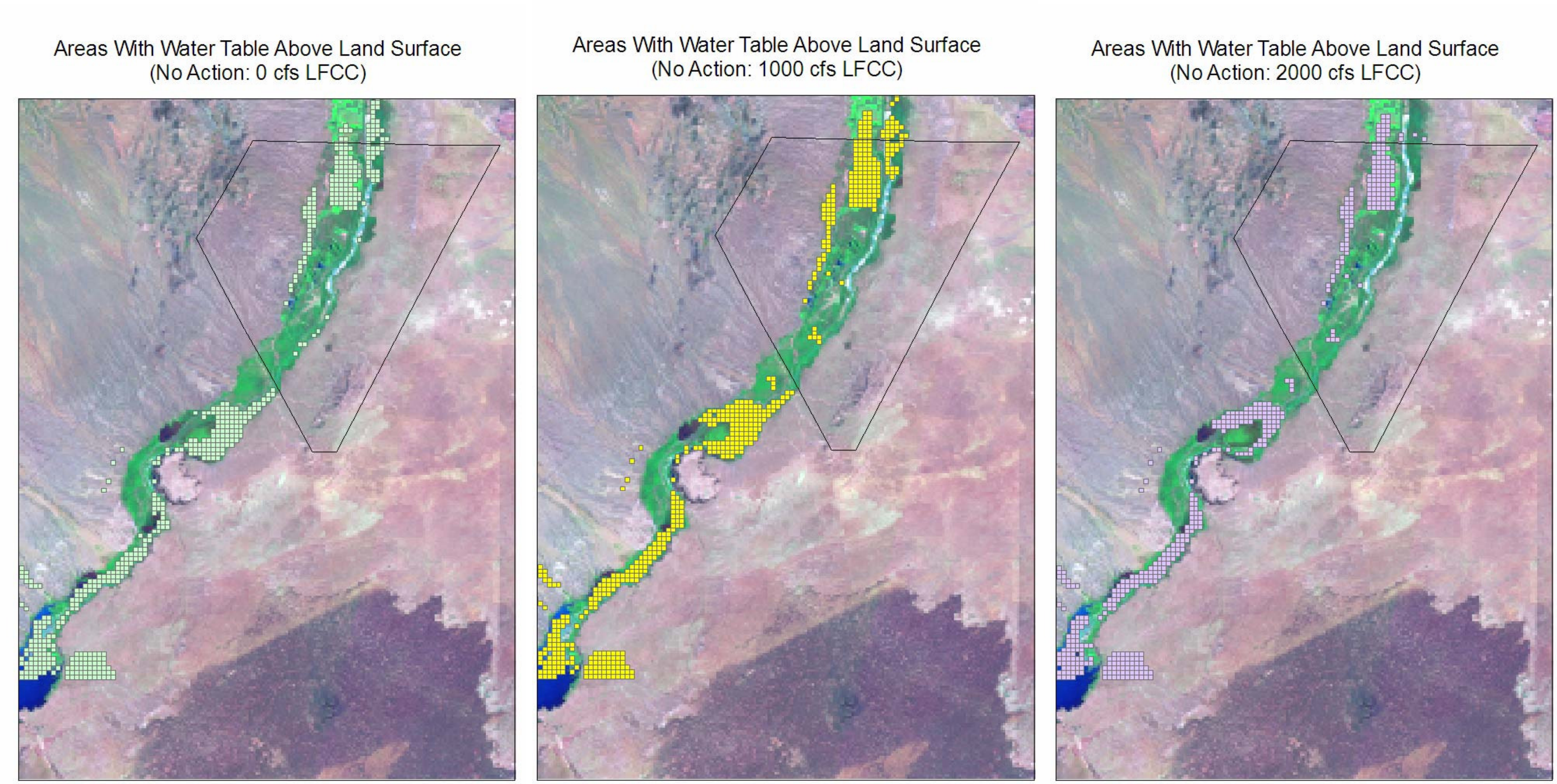


Figure L-3.29 GIS Spatial Analysis: water table greater than lLand surface from Bosque del Apache NWR to Elephant Butte Reservoir

High Flow Duration

All four alternatives, B-3, D-3, E-3, and I-3, reduced the duration of high flows in the Rio Chama section by 37 to 38 percent, reflecting the impact of upstream storage. This reduction in the frequency and magnitude of flow would likely reduce the frequency, duration, or extent of inundation in wetlands within the floodway. As was observed for the low flow durations, storage effects along the Rio Chama are dampened below the confluence with the Rio Grande. The impacts at Otowi gage are reduced, differing only between 5 to 12% from no action. Alternative B-3, with a lesser channel capacity below Abiquiu, offers the potential for sustained higher flow durations due to an extended period of time needed to move water from upstream storage. Central section impacts are similar to those observed at Otowi. Flows in the San Acacia section increased by 13 to 18% for the high storage alternatives. Overall, the duration of the 75th-percentile discharge of the No Action hydrograph was reduced by 4 to 6 percent in alternatives B-3, D-3, E-3 and I-3 (**Table L-3.16**).

The impact of LFCC diversions under these alternatives would mimic the effects shown under No Action at 2,000 cfs. The magnitude and location of wetlands support changes with operation of the LFCC. Areas immediately adjacent and parallel to the LFCC are increasingly supported by operation of the LFCC resulting in higher groundwater elevations and longer durations of high water tables. The areal extent of wetlands near the LFCC would advance. Areas east of the Rio Grande would be adversely affected by diversions of 2,000 cfs as groundwater elevations decline and move below the root zone. (**Table L-2.8**)

Action Alternative I-1

Overall, this alternative exhibited the least changes from the No Action Alternative. Alternative I-1 includes up to 20,000 AF annual storage in Abiquiu Reservoir and LFCC diversions up to 500 cfs. Low-flow durations increased by 8% in the Rio Chama section, but were less than 3% in other river sections. There was no significant change in the duration of high flows when considering all sections individually or combined. Wetlands in the San Acacia section east of the Rio Grande would see no significant changes, with a slight increase in wetlands support expected along the LFCC based on limited diversions.

Action Alternative I-2

This alternative included moderate levels of both storage at Abiquiu Reservoir (up to 75,000 AF annually) and LFCC diversions (up to 1,000 cfs). The increase in duration of low flows—and, therefore, the potential for impact on wetland resources—was relatively small among river sections (1% to 5%) and overall (3 percent).

The duration of high flows was decreased by 20% only in the Rio Chama section, presumably related to the intermediate level of storage in Abiquiu Reservoir. No other significant changes in high flows were observed under this alternative. Similar to the No Action at 1,000 cfs diversions to the LFCC, wetlands in the San Acacia section would be enhanced adjacent to and along the LFCC, and supported with no significant changes in areas east of the Rio Grande.

Designated and Natural Management Areas

It is important to distinguish that, though many management areas lie along the Rio Grande, large portions are outside of the levees mapped for this review and EIS. The vegetation surveys show that between 3- and 5-percent of mapped acreage represents this important habitat type (**Table L-3.16**). However, marsh and wetland habitats extend into the floodplain adjacent to the direct footprint of potential water management changes. Appropriate hydrological support would therefore sustain and improve a larger amount of acres than those represented by the 2002-2004 surveys.

The Rio Chama Section supports the smallest acreage of marsh and wetland habitat, 18% of the total in the Project area. This is followed by the Central Section with approximately 30% the marsh acreage in the Project area, while the San Acacia Section contains over half the marsh and wetland habitats in the entire

Project Area. As shown in **Table L-3.16** and **Figure L-3.30**, Alternative I-1 provides the best hydrological support throughout the Project Area. The No Action exhibits the largest average annual acre-days of inundation in the San Acacia Section, but is basically neutral in the Central Section and performs poorest of all alternatives in the Rio Chama, where this vital habitat type is most in need of continued support.

Table L-3.16 Average Annual Acre-Days of Inundation, by Alternative, for Marsh Habitats

River Section	Mapped Acres	Acres of Marsh	% Total Acres	No Action	B-3	D-3	E-3	I-1	I-2	I-3
Rio Chama	3,073	160	5%	5	11	101	69	114	89	69
Central	11,378	267	4%	146	152	141	153	159	138	127
San Acacia	16,203	463	3%	8128	1777	2038	1535	6833	6357	3653

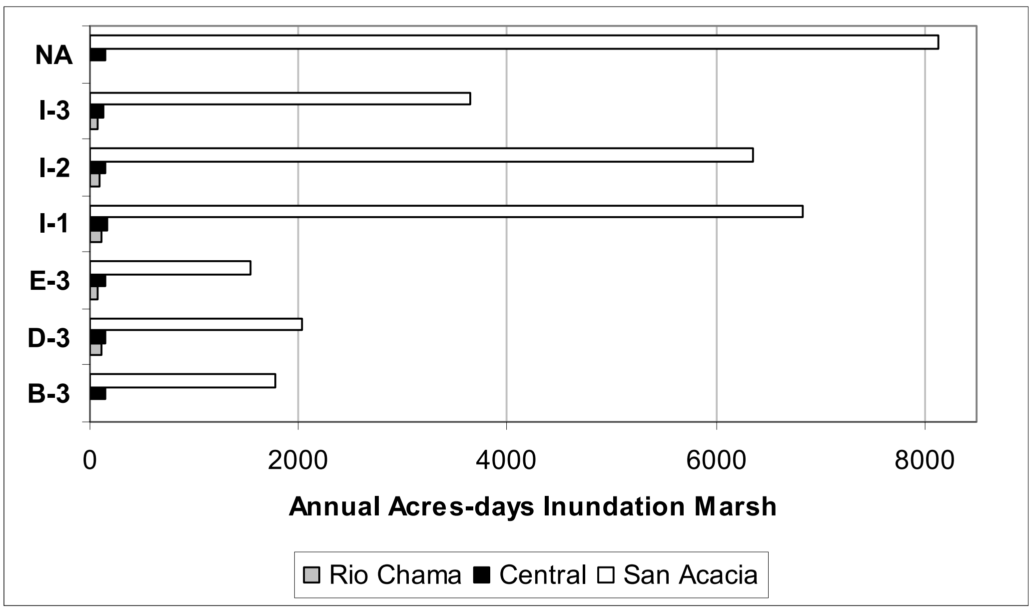


Figure L-3.30 Support of wetland/marsh habitats, by Alternative, as a surrogate for designated and natural management areas.

3.5 *Fauna of the Rio Grande Valley*

3.5.1 *METHODS OF AQUATIC FAUNA ANALYSIS*

The Aquatic Team used available fisheries survey data to establish a baseline condition for both native and non-natives fishes in the Rio Grande Project Area. These data have not been consistently collected over time or by gear type. Therefore, correlations between fish community structure and abundance could not be made against variables such as river flow, or monthly or annual release volume. The Aquatic Team used the Aquatic Habitat Model (Bohannon Huston et al. 2004) output to determine impacts to physical habitat of selected fish species as a surrogate for the general fish community. Additionally, the Team used other instream physical characteristics such as peak flow duration and magnitude, extent of low flow periods, etc. to estimate impacts of action alternatives.

3.5.1.1 Impact Analysis on Aquatic Fauna

As described in the Methods section above, impacts to both riverine and reservoir habitat were used as a surrogate to assess potential impacts to correlated fauna. Therefore, all impact analyses for aquatic fauna are discussed under Section 3.2.1.1 (Impact Analysis on Riverine Resources) and 3.2.2.1 (Impact Analysis on Reservoir Resources).

3.5.2 *Methods of Terrestrial Wildlife Analysis*

As described in Chapter 2, Section 2.3.1.4, the Riparian Team utilized prior wildlife surveys to establish a baseline of the general fauna within the Project Area. Unfortunately, there are no annual wildlife surveys that can verify ongoing effects of the No Action Alternative, against which all Action Alternatives are measured. Therefore, a surrogate was required to assess impacts on riparian fauna. The Hink and Ohmart (1984) data established the correlation between vegetation types and terrestrial wildlife species richness, composition, and habitat associations. Based on those data, the Team determined that vegetation classification Type 3 supported the greatest biodiversity, followed by Type 1, Type 5, and lastly Type 2. These important faunal-usage structures were therefore given the highest weights when determining impacts to riparian fauna: Type 3 = 21.5 percent, Type 1 = 20.7 percent, Type 5 = 19.0 percent, and Type 2 = 14.5 percent. The correlated USFWS Resource Categories are 2 and 3, with Resource Category 2 supporting the highest quantity and diversity of wildlife species. Our criteria thus became an evaluation of which Alternative best supports the chosen Hink and Ohmart / USFWS Resource Category vegetation types. In addition, because overbank flooding is essential to support riparian habitat, our assessment measure is the average acre-days of inundation under each Alternative for water operations throughout the Project Area.

3.5.2.1 Impact Analysis on Terrestrial Riparian Fauna

Analyses applied to all Alternatives

For each Alternative, potential impacts to riparian fauna were weighted according to their hydrological support of Hink and Ohmart structural types known to support the greatest wildlife abundance (**Table L-2.2**, Chapter 2, Section 2.3.1.4). Structural Types 3 and 5 (dense, intermediate height and young vegetation from 5 – 15 ft) are the vegetation classes exhibiting “high” to “very high” usage by birds. The second of only two “very high” bird abundance findings is in Type 1, the mature cottonwood forest with a dense, diverse understory. A high avian abundance indicates these preferred habitats offer the greatest avian support for roosting, nesting, foraging, and lowered predation risks.

Mammal species appear in high abundance *only* in Types 3 and 5, with moderate to low-abundance in Types 1 and 2. These dense structural types afford ideal den or burrow sites for small mammals, as well as protection from predators, particularly raptor species. Types 3 and 5 also support large, diverse invertebrate populations that provide forage for insectivorous mammals, as well as woody species that produce important mast crops.

Reptiles and amphibians were most abundant in Type 4 forest (intermediate height with little to no understory) and Type 6, wherein most vegetation is 5 ft. or under and predominantly forbs, grasses, or immature riparian species such as coyote willow. Reptile and amphibian species are moderate- to mostly low-abundance in structural types with dense, diverse understories; ectotherms require areas open to the sun for control of body temperature.

No Action Alternative

Rio Chama Section

Although the total days of inundation in native vegetation communities for the No Action Alternative is highest among all alternatives in the Rio Chama Section (as shown in Figure L-3.11), the total support to structural types supporting fauna would continue to be low. The acre-days of spring overbank flooding would continue to be very low under No Action. Flooding in Types 1 and 2 mature cottonwood forest and high-value USFWS Resource Category 2 riparian habitats is very infrequent. This lack of support may have contributed to the increase of non-native infestation in the Rio Chama because of the continuing adverse pattern of decline in healthy native forest in this river section. Overall, the No Action would have an adverse impact on the vegetation types required to support healthy populations of associated wildlife, and may promote succession to forests with exotic Russian olive and saltcedar canopy. There would be continued avian presence, but there could be a reduction in mammal, reptile, and amphibian numbers.

While Russian olive is considered a non-desirable exotic, it should be pointed out that this tree provides a high-quality mast crop to wildlife. This is particularly true of insectivorous birds such as robins and northern flickers who switch to berries, nuts, and olives when insects become seasonably unavailable. The No Action would not adversely impact, and may actually benefit, the health of Russian olive and the wildlife species that rely on it for fall and winter forage.

Central Section

Under No Action, overbank flooding would occur somewhere in the Central Section in approximately half of the 40 years modeled. However, only a small acreage on average would receive these flood flows. Vegetation surveys show that both native and exotic vegetation have declined in Hink and Ohmart structural Types 1, 5, and 6. Mixed (native/non-native) species in Types 1 and 4 have also declined.

No Action would provide surface hydrological support to approximately 65% of the vegetated acres in the Central Section. Increases have occurred in mixed vegetation for Types 2, 5, and 6. However, all changes described in the Central Section, whether adverse or beneficial, are inside the determined 15% margin of error and therefore not statistically significant in correlated impacts to riparian fauna.

No Action has supported the largest component of mature riparian forest in the Project area, 34% of which is mature cottonwood gallery forest with a high canopy (Types 1 and 2). Native vegetation in Type 4 has experienced a statistically significant increase under No Action, as has mixed vegetation in Type 3, which supports a high abundance of birds and mammals. These intermediate height riparian forests (Types 3 and 4) account for 35% of the vegetative cover. The Central Section consequently exhibits the vegetation types shown by Hink and Ohmart to contain higher abundance of wildlife species. Type 5 vegetation (5 – 15 ft), which shows high abundance for birds and mammals, is 20% of the vegetation.

Overall, the No Action would be neutral to somewhat-beneficial for riparian fauna in the Central Section.

San Acacia Section

Under No Action, the highest value wildlife habitat in USFWS Categories 2 and 3 would receive approximately 70% of the acre-days of inundation. However, this is not significant because overall, very few of the total acres in this section are actually inundated. In addition, very little of the acre-days of inundation will occur in mature cottonwood forests (Hink & Ohmart Types 1 and 2). Approximately 37% of vegetated acres would receive flood flows in 100% of the modeled years, the highest frequency and area of overbank inundation in the entire study area. In addition, the No Action with zero diversions to the LFCC (**Figure L-3.14**) provides the greatest number of total days of inundation in native vegetation communities of all structural types.

The San Acacia Section suffers the highest infestation of exotic plant species of the three river sections. Heavy infestation by Russian olive (in the canopy) and saltcedar occur mostly in intermediate and young height classes, structural types that support a higher abundance of wildlife families. Salt cedar is used for nesting by species such as the mourning dove. The overall impact of the No Action on San Acacia wildlife would be neutral to slightly beneficial, but not at a significant level.

Action Alternatives

Rio Chama Section

Alternatives B-3, E-3, I-2 and I-3 offer moderate improvements in hydrological support in the Rio Chama Section. Overbank flooding would increase for desirable Hink and Ohmart Types 1 and 2 and for the highest-valued USFWS Resource Category 2 habitat. Types 3 and 5 also receive increased hydrological support. This indicates that Alternatives B-3, E-3, I-2 and I-3 would continue to provide habitat support for most wildlife species associated with the highest-use habitat types. However, reptiles and amphibians are moderate to low in abundance for any structural type with Russian olive as a dominant species. The Rio Chama is the riparian section most heavily infested by this exotic. Therefore, though both birds and mammals would be well-supported by these three Alternatives, hydrological support may sustain or increase Russian olive, indicating low habitat provision for reptiles and amphibians.

Alternatives D-3 and I-1 would have a profound, positive impact on the Rio Chama due to high inundation of possibly extended duration. The percent change in acre-days of inundation compared to No Action on these two alternatives range from +1,861 to +2,167 percent. Figure 3.11 indicated that these alternatives would significantly increase the total days of inundation, but never exceed thresholds of Both The number of days of floodplain indundation per year and the mean annual acres of inundation would increase, without resulting in anoxic conditions. Change in these vegetation structures would be likely, with additional density of understory vegetation and possible increases in native vegetation expected. The associated fauna is likely to change as well. However, the existing dominance of Russian olive would continue to provide the essential food base for the faunal community.

Central Section

All Action Alternatives show basically no change from the No Action Alternative. Percent Change may be slightly negative or beneficial, but most are inside the 15% margin of error and therefore insignificant in their impacts to the vegetation types that support the highest faunal diversity. Alternatives E-3 and I-1 would provide an overall improvement in riparian health for the Central Section via increases in mean annual maximum acres of overbank flooding. Overall, beneficial impacts are probably only statistically significant under Alternatives E-3 and I-1. Improved surface hydrology in the Central Section under these alternatives would probably also result in slightly higher groundwater to support native forests in the area and adjacent wetlands. This should support all wildlife and may benefit amphibian species in particular.

San Acacia Section

Alternative I-1 would have a moderate adverse effect on fauna within the San Acacia Section when compared to No Action. This is primarily because of reduced mean annual maximum acres of overbank flooding. Alternative I-1 is the same as No Action when both were modeled with a 500 cfs diversion to the LFCC.

All other action alternatives have an overall adverse effect on the riparian vegetation and the associated wildlife within the San Acacia Section.

3.6 *Threatened and Endangered Species*

3.6.1 *Methods of Evaluation*

Three federally listed species and one state-listed species were considered in the impacts analysis, based on their known occurrence in areas most likely to be affected by the project. A combined quantitative and qualitative approach was taken in the impact analysis. Quantitative measures focused on long-term changes in available suitable habitat compared with current trends under the No Action alternative. The significance of adverse effects could only be determined through qualitative assessment of the context of the species status and the intensity of the measurable impacts. For example, endangered species within designated critical habitat are considered to have the most sensitive context. Even minor adverse impacts to designated critical habitat would be considered a significant adverse impact.

3.6.1.1 Rio Grande Silvery Minnow Habitat Criteria Description

Riverine Habitat

The change in square feet and per cent changes for the Rio Grande silvery minnow habitat were ranked by alternative for duration of overbank flooding, average number of days of 0 cfs flow, average number of days of flow less than 100 cfs, the average peak flow magnitude, and the average peak flow duration.

The threshold velocity for hatching and retention of RGSM eggs for the reach between Angustura to Elephant Butte reservoir was calculated to be 1.85 feet per second. Any velocities in excess of this threshold result in increased egg and larval mortality as they drift into Elephant Butte reservoir. It is assumed that no recruitment of RGSM eggs or larvae occurs in Elephant Butte reservoir. The frequency of exceeding this velocity threshold was calculated for each alternative.

Reservoir Habitat

Reservoirs are not suitable habitat for Rio Grande silvery minnow and impacts of each alternative on reservoir habitat have been excluded from this section

3.6.1.2 Impact Analysis on Rio Grande Silvery Minnow

Rio Chama Section Overview

Under No Action the Rio Chama section provides the greatest area for potential RGSM habitat over all other alternatives (**Table L-3.2, Table L-3.2**, and **Table L-3.4**). Although no RGSM currently occupy this reach the habitat does exist. For flow related criteria (duration and area of overbank flow, peak flow magnitude and durations, and number of 0 flow and low flow days) the impacts of No Action vary (**Table L-3.5** thru **Table L-3.8**). No Action provides substantially less days of overbank flooding but greater area of overbank flooding for most action alternatives. Peak magnitude and duration of flows is generally greater for No Action. Low flow days are similar under No Action compared to actions alternatives. Riverine habitat for the RGSM is reduced under all alternatives in the Rio Chama Section. Although the modeled RGSM habitat loss in the San Acacia Section and other sections may be inside the margins for error in the study, further habitat reduction should be avoided since it could lead to further declines in this endangered species.

Central Section Overview

Less than 2% reduction in available habitat for RGSM exists between No Action and the Action alternatives (**Table L-3.2**, **Table L-3.3** and **Table L-3.4**). It is likely that no biological significance exists with this small difference. Duration of overbank flows are generally greater under No Action, than all but 3 action alternatives (**Table L-3.5** thru **Table L-3.8**). Overbank area is equal to or less than most action alternatives Peak flow magnitude and duration are higher than most action alternatives, while low flow days are about equal.

San Acacia Section Overview

No Action provides the greatest amount of available habitat for RGSM (**Table L-3.2**, **Table L-3.3**, and **Table L-3.4**) in this section. No Action provides between 9 and 20 percent more available habitat than the

Action alternatives for RGSM. Duration and area of overbank flows for the San Acacia section are greater under No Action (**Table L-3.5** thru **Table L-3.8**). Peak flow duration and magnitude is greater under No Action. Low flow days are fewer under No Action.

Rio Chama Section

Action Alternative B-3 results in the greatest amount of RGSM habitat loss for this river section (**Table L-3.17**). The duration of over bank flooding ranked third highest in magnitude when compared to the other alternatives for this river section and would result in an increase in RGSM habitat when compared to present conditions. The area of overbank flooding ranked sixth in comparison to other alternatives and would reduce RGSM habitat from the no action alternative. There is no impact of this alternative on the average number of no-flow days relative to the no action alternative. This alternative would result in the second lowest average number of days less than 100 cfs of the action alternatives and would decrease the number of days less than 100cfs as compared to current conditions. This would positively impact RGSM habitat in the Rio Chama. Average peak flow magnitude ranked fourth as compared to the other alternatives. However, this alternative would result in a reduction of magnitude relative to the no-action alternative and have a negative impact on RGSM. This alternative ranked first in peak flow duration when compared to other alternatives and would not impact the current level of RGSM habitat.

Table L-3.17 Impacts of the Action Alternatives on RGSM habitat measures in the Rio Chama Section,as rank (measure) and percent change relative to the No Action Alternative

Alternative	Rio Chama Section						
Parameter/ Rank:	RGSM habitat area (sq. ft.)	Duration Overbank (days/year)	Area Overbank (square meters)	0 cfs (days/ year)	<100 cfs (days/ year)	Peak Mag (cfs)	Peak Duration (days/ year)
No Action	55,026	2	477,529	0	9.2	2,900	53.5
B-3	51,021	29	137,593	0	9.1	2,523	53.3
% change	-7%	1350%	-71%	0	1%	-13%	NI
D-3	53,204	28	489,670	0	9.8	2,744	47.1
% change	-3%	1300%	2%	0	-6%	-5%	-12%
E-3	52,790	26	323,749	0	9.4	2,665	49.1
% change	-4%	1200%	-32%	0	-2%	-8%	-8%
I-1	53,522	28	331,842	0	8.9	1,915	53.0
% change	-3%	1300%	-30%	0	3%	-34%	-1%
I-2	52,725	31	396,592	0	9.2	2,789	48.0
% change	-4%	2275%	-17%	0	NI	-4%	-10%
I-3	52,909	37	477,529	0	9.9	2,665	49.1
% change	-4%	1750%	0%	0	-8%	-8%	-8%

Alternative D-3 would have the highest area of overbank flooding in the Rio Chama Section, resulting in an increase in RGSM habitat from the no action alternative. There is no impact of this alternative on the average number of no-flow days relative to the no action alternative. This alternative would result in the second highest average number of days less than 100 cfs of the action alternatives and would increase the number of days less than 100cfs as compared to current conditions. This would negatively impact RGSM habitat. Average peak flow magnitude ranked second as compared to the other alternatives and peak duration ranked fifth. However, this alternative would reduce these parameters relative to the no-action alternative and have a negative impact on RGSM habitat.

Alternative E-3 results in the fourth greatest amount of RGSM habitat loss as compared to other alternatives in the Rio Chama Section. Although the duration of overbank flooding ranked fifth among the alternatives, this still represents a positive increase in this parameter of RGSM habitat. The area of overbank flooding decreased from the no action alternative and was ranked fifth amongst the alternatives and results in a reduction in RGSM habitat. There is no impact of this alternative on the average number of no-flow days relative to the no action alternative. This alternative would result in the fourth highest average number of days less than 100 cfs of the action alternatives and would increase the number of days less than 100cfs as compared to current conditions. This would negatively impact RGSM habitat. Average peak flow magnitude for this alternative (as well as I-3) ranked third compared to the other alternatives. Average peak flow duration would also be ranked third. Both alternatives would reduce these parameters relative to the no-action alternative and reduce RGSM habitat.

Alternative I-1 results in the least amount of RGSM habitat loss as compared to other alternatives for the Rio Chama Section. Duration of overbank flooding ranked fourth highest among the alternatives and represents an increase in this parameter from the no action and a positive impact on aquatic resources. Area of overbank flooding decreased from current conditions under this alternative and negatively impacts riverine resources. Although less than the no action and ranked first among the action alternatives, there is no significant reduction of the average number of no-flow days and average number of days less than 100 cfs in comparison to the no action alternative. Average peak flow magnitude ranked fifth for this alternative, is a reduction in this parameter from the no action, and would result in reduced RGSM habitat. Peak flow duration ranked second when compared to other alternatives and results in no impact to RGSM habitat when compared to the no action alternative.

Alternative I-2 ranked second in the duration of overbank flooding when compared to other alternatives in the Rio Chama. This parameter was greater in magnitude than the no action alternative and would result in improved RGSM habitat. The area of overbank flooding ranked third in comparison to other alternatives and would result in a decrease in RGSM habitat from the no action alternative. There is no impact of this alternative on the average number of no-flow days. This alternative ranks third for average number of days less than 100 cfs as compared to the other action alternatives and results in no change from present conditions. Average peak flow magnitude for this alternative ranked first and average peak flow duration ranked fourth as compared to the other alternatives. These parameters would be reduced relative to the no-action alternative, resulting in a reduction in RGSM habitat.

Alternative I-3 results in the least amount of RGSM habitat loss as compared to other alternatives for the Rio Chama Section. This alternative ranked first in duration of overbank flooding among the alternatives and would result in an increase in RGSM habitat in comparison to the no action alternative. The area of overbank flooding for this alternative equaled the no action alternative and would result in no habitat change for the RGSM. There is no impact for this alternative on the average number of no-flow days relative to the no action alternative. This alternative would result in the greatest average number of days less than 100 cfs of the action alternatives and would negatively impact RGSM habitat as compared to current conditions. Average peak flow magnitude and average peak flow duration for this alternative both ranked third. However, this alternative would reduce these parameters relative to the no-action alternative and have a negative impact on RGSM habitat.

Central Section

For this river section, Alternative B-3 would result in the greatest amount of RGSM habitat loss (**Table L-3.18**). Over bank flooding duration would be the fourth highest of the alternatives and result in a decrease in over bank flooding and a negative impact on RGSM habitat relative to current conditions. Beneficial effects of this alternative include increases in the area of overbank flooding that would result in a positive increase in RGSM habitat from the no action alternative. This alternative would also result in the least number of no-flow and <100 cfs days and would reduce these parameters relative to current conditions and have a positive impact on RGSM habitat. Average peak flow magnitude ranked third as compared to the other alternatives but result in a reduction of RGSM habitat compared to current conditions. Average peak flow duration ranked fifth and result in a reduction of current peak flow durations negatively impacting RGSM habitat.

Alternative D-3 would result in decreased duration but increased area of over bank flooding compared to the No Action alternatives for the Central Section. This alternative (as well as E-3, I-1, I-2, and I-3) ranked second for the number of no-flow days among the alternatives. However, this alternative would result in a small increase in the number of no-flow days from the no action alternative and have a slightly negative impact on RGSM habitat. This alternative had the same number of <100 cfs days as the no action alternative (along with E and I-1) and, therefore, would have no affect on RGSM habitat in this section of the river. Average peak flow magnitude and duration ranked fourth as compared to the other alternatives and result in a reduction of RGSM habitat relative to the no-action alternative.

Table L-3.18 Impacts of the Action Alternatives on RGSM habitat Measures in the Central Section, as Rank (measure) and percent Change Relative to the No Action Alternative

Alternative	Central Section						
Parameter/ Rank:	RGSM habitat area (sq. ft.)	Duration Overbank (days/year)	Area Overbank (square meters)	0 cfs (days/ year)	<100 cfs (days/ year)	Peak Mag (cfs)	Peak Duration (days/ year)
No Action	1,224,029	15	1,545,899	15.4	32.8	3,969	47.8
B-3	1,200,176	11	2,731,628	15.3	32.3	3,847	43.6
% change	-2%	-27%	+77%	+1%	+2%	-3%	-9%
D-3	1,206,690	13	1,663,258	15.5	32.8	3,768	44.4
% change	-1%	-13 %	+8%	-1%	NI	-5%	-7%
E-3	1,204,042	9	2,938,018	15.5	32.8	4,011	42.3
% change	-2%	-40%	+90%	-1 %	NI	+ 1%	-12%
I-1	1,217,438	12	1,424,493	15.5	32.8	4,045	46.9
% change	-0%	-20%	-8 %	-1%	NI	+ 2%	-2%
I-2	1,204,580	13	1,598,508	15.5	33.1	3,868	45.0
% change	-2%	-13%	3 %	-1%	-1%	-3%	-6%
I-3	1,203,105	16	1,800,851	15.7	33.1	3,715	45.5
% change	-2%	+6.7%	-16%	-2%	-1%	-6%	-5%

Alternative E-3 (as well as I-2) results in the second greatest amount of RGSM habitat loss as compared to other alternatives in this section. Over bank flooding duration ranked fifth and overbank flooding area ranked first in comparison to the other alternatives. However, both are a reduction in these parameters from the no action alternative and, therefore, decrease RGSM habitat in this river section. This alternative (as well as D-3, I-1, and I-2) ranked second for the number of no-flow days as compared to the other action alternatives. The alternative would result in a slight increase in the average number of no-flow days compared to no action and would reduce RGSM habitat. This alternative would have no impact on the average number of <100 cfs days compared to current conditions and would not affect RGSM habitat. Average peak flow magnitude ranked second as compared to the other alternatives and result in an increase in RGSM habitat. Average peak flow duration ranked sixth as compared to the other alternatives and would result in a reduction in RGSM habitat relative to the no-action alternative.

Alternative I-1 results in the least amount of RGSM habitat loss as compared to other alternatives. Over bank flooding duration would be reduced from the no action alternative and ranks third when compared to the other alternatives. Area of overbank flooding is also reduced from the current conditions and ranks fifth when compared to the other alternatives. These reductions would adversely affect RGSM habitat. There alternative results in no change on the average number of no-flow days and average number of days less than 100 cfs relative to the no action alternative and both criteria rank second as compared to the other action alternatives. Average peak flow magnitude ranked highest compared to the other alternatives and result in an increase in average magnitude relative to current conditions and positively affect RGSM habitat. Average peak flow duration ranked greatest as compared to the other alternatives. However, this alternative would result in a reduction of peak flow duration relative to the no-action alternative and negatively affect RGSM habitat.

Alternative I-2 (as well as E-3) results in the third greatest amount of RGSM habitat loss as compared to other alternatives for this section of the river. Over bank flooding duration for this alternative (as well as D-3) ranked second in magnitude when compared to the other alternatives. This parameter would be reduced relative to current flooding conditions and would have a negative impact on RGSM habitat. Over bank flooding area for this alternative ranked fifth among the alternatives. This parameter, however, would be increased relative to current flooding conditions and would have a positive impact on the RGSM habitat. Average number of no-flow days ranked second (along with three other alternatives) and would result in no impact to habitat when compared to present conditions. The average number of <100 cfs, average peak flow magnitude, and average peak flow duration for this river section would each be ranked third as compared to the other action alternatives. However, these parameters for this alternative would reduce RGSM habitat relative to the no-action alternative.

Alternative I-3 ranks fourth in the amount of RGSM habitat loss as compared to other alternatives. Duration of over bank flooding duration ranked first when compared to other alternatives and would increase RGSM habitat over present conditions. This alternative ranked third in comparison to other alternatives for area of overbank flooding and would increase RGSM habitat over current conditions. This alternative ranked last for the number of no-flow days as compared to the other action alternatives and result in an increase in the number of no-flow days. This would have negative impacts on RGSM habitat. The average number of days less than 100 cfs for this alternative (as well as I-2) ranked third as compared to the other alternatives and would increase this parameter as compared to current conditions. This would negatively impact RGSM habitat. Average peak flow magnitude ranked fifth and average peak flow duration ranked second as compared to the other alternatives. However, this alternative would result in a reduction these parameters relative to the no-action alternative and have a negative impact on the RGSM habitat.

San Acacia Section

Over bank flooding duration for this Alternative B-3 is the fourth highest of the alternatives for this section of the river (**Table L-3.19**). This alternative ranked fifth in area of overbank flooding. Both of these parameters would be reduced relative to current flooding conditions and would have a negative impact on RGSM habitat. Data were not available on no-flow days for this reach. This alternative (as well as I-3) ranked fourth for the number of days <100 cfs as compared to the other action alternatives and result in a decrease in this parameter relative to current conditions, which would have negative impacts on RGSM habitat. Average peak flow magnitude ranked fourth compared to the other action alternatives. This alternative is ranked second in average peak flow duration as compared to the other alternatives. However, both of these parameters would be reduced and result in negative impacts on RGSM habitat for the San Acacia section.

Alternative D-3 results in the greatest amount of RGSM habitat loss as compared to other alternatives. Over bank flooding duration for this alternative is the fourth highest of the alternatives for this river section. This alternative ranked fifth in area of overbank flooding. Both of these parameters would be reduced relative to current flooding conditions and would have a negative impact on RGSM habitat. Data were not available on no-flow days for this river reach. This alternative (as well as I-3) ranked fourth for the number of days, 100 cfs as compared to the other action alternatives and results in a decrease in this parameter relative to current conditions, which would have negative impacts on RGSM habitat. Average peak flow magnitude ranked fourth compared to the other action alternative. This alternative is ranked. second in average peak flow duration as compared to the other alternatives. However, both of these parameter would be reduced and result in negative impact on RGSM habitat for the San Acacia Section under this alternative.

Alternative E-3 results in the third greatest amount of RGSM habitat loss as compared to other alternatives in this section of the river. Over bank flooding duration for this alternative ranked last among the alternatives. This alternative (as well as B-3) ranked fourth for the area of over bank flooding. Both of these parameters would be reduced relative to current flooding conditions and would have a negative impact on RGSM habitat. Data were not available on no-flow days for this reach. The number of <100 cfs days for this river section ranked third as compared to the other action alternatives resulting in an increase in this parameter relative to current conditions and has negative impacts on RGSM habitat. Average peak flow magnitude ranked second and average peak flow duration ranked fifth compared to the other alternatives. However, these parameters would be reduced and result in negative impacts to RGSM habitat.

Alternative I-1 results in the least amount of RGSM habitat loss as compared to other alternatives. Over bank flooding duration and area ranked third for this alternative and represents a reduction in both of these parameters when compared to the no action alternative. The changes would result in negative impacts to RGSM habitat. Data were not available on no-flow days for this reach. The number of <100 cfs days for this river section ranked first as compared to the other action alternatives and results in an increase in this parameter relative to current conditions. This would have negative impacts for this parameter on RGSM habitat. Average peak flow magnitude and average peak flow duration for this alternative reach ranked first compared to the other alternatives. However, this alternative would reduce these parameters relative to the no-action alternative and have a negative impact on RGSM habitat.

Alternative I-2 results in the second to the least amount of RGSM habitat loss as compared to other alternatives. Over bank flooding duration and area for this alternative ranked second compared to the other alternatives. Both of these parameters would be reduced relative to current flooding conditions and would have a negative impact on RGSM habitat. Data were not available on no-flow days for this reach. The number of <100 cfs days for this alternative (as well as D-3 and I-3) ranked fourth as compared to the other action alternatives and results in an increase in this parameter relative to current conditions, which would have negative impacts on RGSM habitat. Average peak flow magnitude for this alternative (as well as I-1) ranked first as compared to the others. Average peak flow duration for this alternative (as well as D-3) ranked second. However, this alternative would reduce these parameters relative to the no-action alternative and have negative impacts on RGSM habitat.

Alternative I-3 ranks fifth in the amount of RGSM habitat loss as compared to other alternatives. Over bank flooding duration and area for this alternative ranked first when compared to the other alternatives. However, these parameters would be reduced relative to current flooding conditions and have a negative impact on RGSM habitat. Data were not available on no-flow days for this reach. Average number of days less than 100 cfs for this alternative (as well as D-3 and I-2) ranked fourth as compared to the others and would increase this parameter as compared to current conditions. This would negatively impact RGSM habitat. Average peak flow magnitude ranked fifth and average peak flow duration ranked third as compared to the other alternatives. However, this alternative would result in a reduction these parameters relative to the no-action alternative and have a negative impact on the RGSM habitat.

Table L-3.19 RGSM impacts in the San Acacia Section by alternative and measure compared to No Action Alternatives with equal diversions to the LFCC

San Acacia Section with Diversions		RGSM Measure with percent Change from No Action with Equal Diversion to LFCC						
Alternative	LFCC Diversion	RGSM habitat area (sq. ft.)	Duration Overbank (days/year)	Area Overbank (square meters)	0 cfs (days/ year)	<100 cfs (days/ year)	Peak Mag (cfs)	Peak Duration (days/ year)
No Action	0 Diversion	511,468	33	8,789,772	0	98.7	3,578	39.3
No Action	500 cfs	460,499	No data	7,119,713	69	214	3,205	33.6
I-1	500 cfs	458,599	16	4,386,792	No data	106.4	2,713	34.1
% change		0%		-38%		-49%	-15%	-1.5%
No Action	1,000 cfs	422,677	No data	5,361,761	69	214	2,774	29.0
I-2	1,000 cfs	425,146	27	7,952,073	No data	109.2	2,703	28.8
% change		+1%		+48%		-49%	-2.6%	-0.7%
No Action	2,000 cfs	434,974	No data	2,461,136	69	214	2,398	26.4
B-3	2,000 cfs	406,647	10	2,679,019	No data	107.8	2,006	26.2
% change		-6%		+9%		-50%	-16.3%	-0.8%
D-3	2,000 cfs	405,634	11	2,375,505	No data	109.6	1,922	28.9
% change		-7%		-3%		-49%	-19.8%	+10.2%
E-3	2,000 cfs	406,879	8	2,606,176	No data	109.0	2,153	25.5
% change		-6%		+6%		-49%	-10.2%	-3.4%
I-3	2,000 cfs	405,731	29	8,251,540	No data	109.6	1,860	27.5
% change		-7%		+235%		-49%	-22.4%	+4.2%

RGSM Juvenile and Adult Habitat Impacts During Spring Only

Habitat availability data for each alternative were separated into adult and juvenile habitat (ft2) for spring months (April1-June 30) and compared to the No Action alternative RGSM habitat availability for both life stages combined on an annual basis. **Table L-3.20** summarizes the data for this discussion.

No Action

Rio Chama Section

Spring period habitat for RGSM juvenile and adults was equal to or slightly lower for the No Action alternative. RGSM are not currently found in the Rio Chama at this time. The 5 – 6 percent differences may not be biologically significant.

Central Section

Spring period habitat for RGSM is similar under No Action compared to action alternatives.

San Acacia Section

Spring period habitat for RGSM is greater under No Action by about 4 to 16 percent compared to action alternatives. This difference may be biologically significant.

Table L-3.20 RGSM Riverine Spring Habitat percent Change Relative to No Action Adult and Juvenile RGSM by Alternative

Alternative	Rio Chama Section			Central Section			San Acacia Section		
Parameter/ Rank:	Juvenile habitat – Spring	Adult habitat – Spring	Adult & juvenile habitat – Annual	Juvenile habitat – Spring	Adult habitat – Spring	Adult & juvenile habitat – Annual	Juvenile habitat – Spring	Adult habitat – Spring	Adult & juvenile habitat – Annual
B-3	1.7	3.9	-7.3	0.6	-1.5	-1.9	-15.4	-15.6)	-19.7)
D-3	5.2	6.1	-3.3	0.7	-1.1	-1.4	-15.9	-16.5	-19.9
E-3	4.7	6.0	-4.1	0.8	-1.2	-1.6	-15.1	-15.5	-19.6
I-1	0.3	0.3	-2.7	-0.2	-0.1	-0.5	-4.0	-4.5	-9.4
I-2	1.9	2.3	-4.2	0.4	-0.6	-1.6	-8.8	-9.4	-16
I-3	5.0	6.3	-3.8	0.5	-1.3	-1.7	-15.8	-16.3	-19.8

Alternative B-3

Rio Chama Section

All of the alternatives in this section gained juvenile and adult RGSM habitat relative to the No Action Alternative. This alternative ranks fifth in the amount of spring habitat gained for both adult and juvenile RGSM.

Central Section

Juvenile spring habitat area created by this alternative ranks third among the other alternatives. This alternative results in an increase in juvenile RGSM spring habitat but the greatest reduction in adult habitat when compared to the other alternatives for this section.

San Acacia Section

All of the alternatives in this river section lost significant amounts of juvenile and adult RGSM habitat in comparison to the No Action alternative. This alternative ranks fourth for the least amount of adult and juvenile spring habitat loss.

Alternative D-3

Rio Chama Section

RGSM juvenile and adult habitat area is not reduced for this alternative relative to the area of habitat for the No Action alternative. Juvenile habitat area is greatest for this alternative and ranks second in the amount of spring habitat gained for adult RGSM for this section.

Central Section

This alternative results in the second greatest increase in juvenile RGSM spring habitat, but the third greatest reduction in The third highest adult habitat reduction is incurred under this alternative for this river.

San Acacia Section

Spring RGSM juvenile and adult habitat area is reduced relative to the availability of habitat for the No Action alternative. This alternative results in the greatest amount of adult and juvenile spring habitat loss for this reach and alternative.

Alternative E-3

Rio Chama Section

RGSM juvenile and adult habitat area is not reduced for this alternative relative to the area of habitat for the no Action alternative. Juvenile and adult habitat area rank third in the amount of spring habitat gained.

Central Section

This alternative results in the greatest increase in juvenile RGSM spring habitat but the fourth greatest reduction in adult habitat for this reach of the river.

San Acacia Section

Spring RGSM juvenile and adult habitat area is reduced relative to the availability of habitat for the No Action alternative. This alternative ranks third in the amount of adult and juvenile spring habitat lost for this reach.

Alternative I-1

Rio Chama Section

RGSM juvenile and adult habitat area is not reduced for this alternative relative to the area of habitat for the no Action alternative. This alternative results in the least amount of juvenile and adult habitat area gained for this section among all alternatives.

Central Section

This alternative results in adult and juvenile habitat loss relative to the No Action alternative. This alternative results in the only loss of juvenile RGSM spring habitat among the alternatives for this section. All alternatives lost adult habitat in this section but this alternative recorded the lowest reduction of all.

San Acacia Section

This alternative results in the least amount of adult and juvenile spring habitat loss of all alternatives in this section relative to the No Action alternative.

Alternative I-2

Rio Chama Section

RGSM juvenile and adult habitat area increase under this alternative relative to the area of habitat under the No Action alternative. This alternative results in the fourth greatest amount of juvenile and adult habitat area gained.

Central Section

This alternative results in the fifth greatest increase in juvenile RGSM spring habitat but the second lowest reduction in adult habitat.

San Acacia

This alternative results in the second least amount of adult and juvenile spring habitat loss relative to the no Action alternative.

Alternative I-3

Rio Chama Section

RGSM juvenile and adult habitat increase under this alternative relative to the area of habitat under the No Action alternative. This alternative results in the second greatest gain of juvenile and the greatest amount of adult habitat area gained.

Central Section

This alternative results in the fourth greatest increase in juvenile RGSM spring habitat but the fifth greatest loss in adult habitat for this section in comparison to the No Action alternative.

San Acacia Section

This alternative results in the fifth greatest amount of adult and juvenile spring habitat loss relative to the No Action alternative for this section.

RGSM Velocity Impacts

Analysis of Rio Grande silvery minnow (RGSM) egg retention, transport, and entrainment was accomplished using the results of the FLO-2D and the URGWOM model. It was assumed that Rio Grande silvery minnow spawn during flow increases in spring (May-June) and that its eggs are uniformly distributed in the water column. The average flow velocity during spawning was quantified by each reach of interest for the 40-year period of record by alternative.

The FLO-2D Model was used to predict average water velocity of the study reaches for a range of discharge events during spring runoff by alternative. The general egg transport rate was estimated using average water velocity data for the reach of interest for a range of flows. The reach of interest was Angostura Diversion Dam to the headwaters of Elephant Butte Reservoir. **Figure L-3.31** shows the frequency (by percent) at which the threshold velocity, under each Alternative, would exceed 1.85 fps for that river reach.

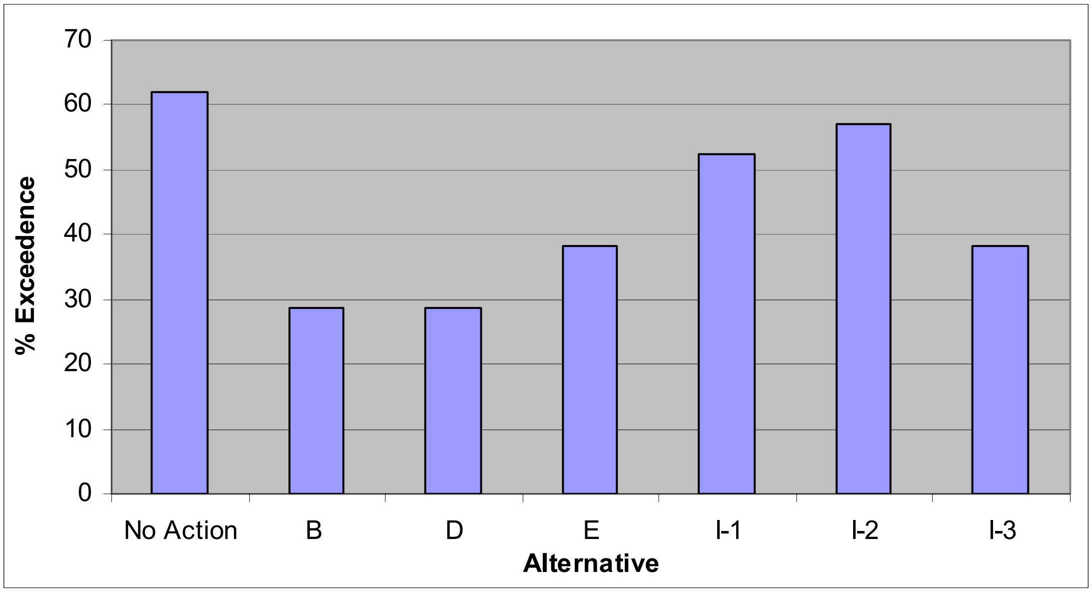


Figure L-3.31 Percent frequency of exceedance of threshold velocity for all alternatives.

No Action

Current operations result in velocities surpassing the threshold velocity 62% of the time, resulting in the greatest frequency of threshold velocity exceedance of all the alternatives.

Alternative B-3

This alternative (as well as D-3) produces velocities that surpass the threshold velocity 28.5% of the time and results in the least frequent exceedance of the threshold velocity.

Alternative D-3

This alternative (as well as B-3) produces velocities that surpass the threshold velocity 28.5% of the time and results in the least frequent exceedance of the threshold velocity.

Alternative E-3

This alternative (as well as I-3) produces velocities that surpass the threshold velocity 38% of the time and results in the second least frequent exceedance of the threshold velocity.

Alternative I-1

This alternative produces velocities that surpass the threshold velocity 52% of the time and results in the third least frequent exceedance of the threshold velocity.

Alternative I-2

This alternative produces velocities that surpass the threshold velocity 57% of the time and results in the fourth least frequent exceedance of the threshold velocity.

Alternative I-3

This alternative (as well as E-3) produces velocities that surpass the threshold velocity 38% of the time and results in the second least frequent exceedance of the threshold velocity.

3.6.1.3 Southwestern Willow Flycatcher Habitat Criteria Description

Criteria for SWFL habitat suitability determination.

Vegetation maps using the modified Hink and Ohmart vegetation classifications along with classifications of occupied SWFL breeding sites were used to determine unoccupied areas that have a higher probability to support breeding SWFLs based on vegetation structure, composition, height and density (**Table L-3.21**and **Table L-3.22**). We classified all polygons as suitable if the structure type classification is 1, 3, 4, and 5, and if the understory plants are dominated by the riparian plants – willow, cottonwood, saltcedar or Russian olive. Polygons were considered to have very low potential to be suitable and were excluded if the structure type is 2 and 6, the understory vegetation is not dominated by willow, cottonwood, saltcedar or Russian olive, or the understory was found to be sparse. In our subsequent analysis, all polygons that were greater than 50 m from the river channel or ponds were excluded and determined to be unsuitable.

In many cases, areas within certain polygons classified as suitable may not be dense enough to support breeding flycatchers. However, since the classifications often represent average vegetation structure within the polygon and may contain micro-sites of denser vegetation that were too small for our mapping to detect, we classified a broader range of polygons as suitable and probably overestimated the extent of suitable habitat. Polygons that were exceptionally dense or had a high proportion of willow in both the overstory and understory were classified as most suitable.

Vegetation characteristics
Southwestern willow flycatcher (SWFL) breeding territories are established in dense riparian vegetation, ranging in height from about 6 to 98 feet, usually with dense foliage in the lower shrub layer (Fish and Wildlife Service, 2002 *Recovery Plan*). The lower heights of SWFL habitat (6-10 ft.) are more characteristic of montane SWFL habitat. The height of occupied SWFL habitat on the Middle Rio Grande always exceeds 10 feet, and is often higher, averaging from 12 to 29 feet. (Ahlers and White, 1996; Moore and Ahlers, 2004).

Breeding SWFLs on the Rio Grande demonstrate a preference for willow dominated habitat, although they will breed in saltcedar. For SWFL nests found from 1999 to 2003, 79.4% were in willow-dominated habitat, 11.2% were found in mixed habitat, and 9.4% were in saltcedar dominated habitat *(n=267)* (Moore and Ahlers, 2004). However, when considering nest substrate, the same study found that 56.2% of the nests were placed in a willow plant, 39.7% were placed in a saltcedar, and 4.1% were placed in a Russian olive. There were no significant differences between vegetation type and nest success.

Table L-3.22 and **Table L-3.23** list modified Hink and Ohmart vegetation classifications where nests have been found since 2000. These classifications often represent average vegetation structure within a delineated polygon, but SWFLs appear to select microhabitat features with a patch for nesting. For example, preliminary nest site quantification has revealed that SWFLs prefer to nest in micro-sites with the highest foliage density in the vertical zone from 6 to 20 feet above the nest (Moore and Ahlers, 2004).

Hydrology
Nesting SWFLs prefer areas near surface water or in flooded vegetation, at least early in the breeding season or during initial establishment of nesting territories. Overbank flooding is an essential function of a healthy riparian ecosystem and is necessary to establish and maintain suitable SWFL habitat. However, site fidelity compels certain nesting SWFLs to return to dry previously occupied sites that are farther away from surface water during dry periods. It is unknown how many years a site would remain dry or at an increased distance from surface water to cause SWFLs to abandon it

During nest monitoring studies on the Middle Rio Grande from 1999 to 2003, the vast majority of nests have been found within 164 feet (50 m) of surface water (Darrell Ahlers, personal communication). The average distance to water was 78.4 feet and the range was from 0 to 482 feet. About 41% of the nests were in flooded habitat, 90% of nests were less than 164 feet from surface water, and 95% were less than 328 feet. About 97% of nests were within 164 feet of surface water when the site was first occupied by nesting SWFLs sometime in previous years, and all the sites have experienced flooding sometime in the past.

Table L-3.21 Native Dominated Riparian Vegetation Communities with Known SWFL Territories and Nests, 2000-2004 (Modified Hink and Ohmart Vegetation Classifications)

Native overstory/ native understory	# Nests & territories	Native overstory/ exotic understory	# Nests & territories
TW4	149	TW-C/SC-CW3	8
TW/TW-SC3	59	TW-C/SC3	4
TW/TW-CW3	49	C/SC-RO1	2
C-TW/SC-TW3	33	TW/SC3	2
TW4F	15	C/RO-CW1F	1
C-TW/CW-TW3	8	C/SBM-SC3	1
TW5	6	C/SC1	1
C4	5	C/SC3	1
CW5	3	C/SC-B/RO3	1
CW5F	3	C-SC/SC-NMO1	1
C/TW3S	1	TW/SC1	1
C-CW5	1	TW-C/SC1	1
C-SBM-SC5	1		
CW-SC5F	1		
TW-C/TW-SC-CW3	1		
Total	**335**		**24**
Percent	**77.55%**		**5.56%**

Table L-3.22 Non-Native Dominated Riparian Vegetation Communities with Known SWFL Territories and Nests, 2000-2004 (Modified Hink and Ohmart Vegetation Classifications)

Exotic overstory/ native understory	# Nests & territories	Exotic overstory/ exotic understory	# Nests & territories
RO/CW3	8	SC4F	34
		RO/SC3	10
		RO4	6
		RO-C/SC3	4
		SC4	4
		RO-CW-C5	2
		SC5	2
		SC-TW-C/SC-B3	2
		SC-RO-B5	1
Total	**8**		**65**
Percent	**1.85%**		**15.05%**

Key to Vegetation Types:

- A forward slash (/) indicates separation between overstory species / understory species
- A hyphen (-) separates species, in order of prevalence, within either the over- or understory
- Numbers indicate Hink and Ohmart structural types 1 thru 6

Legend for Tables L-3.22 and L-3.23:	B = Baccharis C = Cottonwood CW = Coyote Willow	NMO = New Mexico Olive RO = Russian Olive SBM = Screwbean Mesquite	SC = Salt Cedar TW = Tree Willow

SWFL Analysis Assumptions

- Riparian vegetation at least 6 feet in height (10 ft or greater is preferred for the middle Rio Grande) with dense vegetation (>74% cover) in the understory could be suitable SWFL breeding sites.
- Suitable breeding sites are within 164 feet of surface water (Rio Grande channels, ponds, wetlands, etc.
- Overbank flooding of suitable habitat greatly increases its habitat value and sustainability.
- SWFLs are more likely to disperse and establish new breeding sites closer to existing breeding sites than further away.
- Overbank flooding is essential to create new habitat

SWFL Analysis Methods

- Overlay all known current and recent SWFL occupied habitat patches (1999-2004) on the vegetation maps and FLO-2D inundation maps. This does not include the occupied habitat within the pool of Elephant Butte Reservoir.
- The FLO-2D model is used to determine the following indicators of SWFL habitat quality for the occupied sites for each reach:

  40-year frequency of inundation

  Mean/Max duration of non-inundation (years)

  Mean annual acre-day of inundation

  Maximum annual acre-day of inundation

Based on synthesis of knowledge of SWFL habitat use in the Middle Rio Grande and habitat requirements presented by the Fish and Wildlife Service in the 2002 Recovery Plan, it was determined which Hink and Ohmart Vegetation types have the best potential to be suitable SWFL breeding habitat (**Table L-3.23**). Conversely, **Table L-3.24** determines the mapped vegetation classifications that are least likely to provide suitable SWFL habitat.

Occupied SWFL breeding sites and Hink and Ohmart polygons determined to be suitable SWFL habitat and that are within 164 feet (50 meters) of surface water were incorporated into FLO-2D model to determine the degree of inundation as an index of habitat quality and sustainability. Those polygons were separated into two zones – within 10 miles of habitat that has been occupied for the last 5 years and greater than 10 miles. For each of the two zones, and for each reach, the following indicators were determined from the FLO-2D model.

- 40-year frequency of inundation
- Mean/Max duration of non-inundation (years)
- Mean annual acre-days of inundation
- Maximum annual acre-days of inundation

In our assessment, more value is given to inundation of suitable habitat within 10-miles of currently occupied habitat due to the increased probability of SWFLs moving into suitable habitat in proximity to occupied habitat.

Key to Vegetation Types for **Table L-3.24** and **Table L-3.25**:

- A forward slash (/) indicates separation between overstory species / understory species
- A hyphen (-) separates species, in order of dominance, within either the over- or understory
- Numbers indicate Hink and Ohmart structural types 1 thru 6

Table L-3.23 Hink and Ohmart Vegetation Codes Selected as Best Potential to be Suitable SWFL Breeding Habitat

Selected Vegetation Types for Suitable SWFL breeding habitat				
B-C5	C/SC-CW3	C-SC5	Q-TW4	SC-CW5
B-C-RO5S	C/SC-CW5	C-SC-RO5	RO/C-SC3	SC-CW-C5
B-CW5	C/SC-CW-MB3	C-SE/CW3	RO/CW3	SC-CW-TW-B5
B-CW5F	C/SC-HMS3	C-SE/RO1	RO/CW3F	SC-R04
B-CW-C5	C/SC-MB1	C-SE/RO-CW1	RO/CW-B3	SC-RO/SC3
B-CW-SC5	C/SC-NMO1	C-SE/SC1	RO/CW-B-SBM3F	SC-RO/SC-RO3
B-SC5	C/SC-NMO3	C-SE/SC-SE1	RO/CW-C3	SC-RO/TW-SE3
B-SC5S	C/SC-RO1	C-TW/CW3	RO/CW-SC3	SC-RO4
B-SC-CW5	C/SC-RO3	C-TW/CW-SC1	RO/NMO-RO3	SC-RO5
B-SC-RO5S	C/SC-RO-CW1	C-TW/CW-TW3	RO/RO3	SC-RO-B5
C/C-CW3F	C/SC-RO-CW3	C-TW/MB-SC1	RO/RO-CW3	SC-RO-C5
C/C-CW-SC3	C/SC-RO-CW-B3	C-TW/NMO3	RO/RO-CW5	SC-RO-CW5
C/CW1	C/SC-RO-MB1	C-TW/RO3	RO/RO-SC3	SC-RO-SE/SC-RO3
C/CW3	C/SC-RO-SBM3	C-TW/RO-SC3	RO/SC3	SC-SB5
C/CW3F	C/SC-RO-TW1	C-TW/SC1	RO/SC5	SC-SBM5
C/CW-MB1	C/SC-RO-TW3	C-TW/SC3	RO/SC-CW3	SC-SS5
C/CW-NM03	C/SC-SBM1	C-TW/SC-CW3	RO/SC-RO3	SC-TW5
C/CW-NMO3	C/SC-SBM3	C-TW/SC-RO1	RO3	SC-TW5F
C/CW-RO1	C/SC-TW1	C-TW/SC-TW3	RO4	SC-TW-C/SC-B3
C/CW-RO3	C/SE-MB-RO1	C-TW/TW-SC3	RO5	SC-TW-NMO/ SC-TW-NMO3
C/CW-RO-SC3	C/SE-RO1	C-TW4	RO5F	SE/CW3
C/CW-RO-TW1	C/TH-SE-CW3	C-TW5	RO5S	SE/RO-CW5
C/CW-SC1	C/TW-CW-RO1	C-TW-CW5	RO-ATX-SC5	SE/SC3
C/CW-SE-MB1	C/TW-RO-SC1	CW4	RO-C/B-SC-RO3	SE-C/RO-SC3
C/ERNA-CW3	C/TW-SC3	CW5	RO-C/CW3	SE-C/SC3
C/MB-RO1	C4	CW5F	RO-C/CW-SC3	SE-C/SC-TH3
C/NMO-CW3	C5	CW-B5	RO-C/RO-C3	SE-CW5
C/NMO-CW4	C5F	CW-B5F	RO-C/SC3	SE-RO/RO3
C/NMO-RO1	C-B-CW5	CW-B-C5	RO-C/SC-B-C3	SE-RO/SC3
C/NMO-SC-RO1	C-B-RO5	CW-B-C5F	RO-C4	SE-RO/SC-CW5
C/R01	C-CW4	CW-B-RO-C5	RO-C5	SE-RO-TW5
C/RO/SC1	C-CW5	CW-C5	RO-C-SC5	SE-TW-C/SC-RO3
C/RO1	C-CW5F	CW-C5F	RO-C-TW/CW3	TW/CW3
C/RO1F	C-CW-B5	CW-C-B5F	RO-CW5	TW/CW-NMO3
C/RO3	C-CW-RO5	CW-C-CAT5	RO-CW5F	TW/CW-SC3
C/RO5	C-CW-RO5F	CW-C-RO5	RO-CW-C5	TW/CW-TW3
C/RO-CW1	C-CW-RO-SC5	CW-C-RO-SC5	RO-CW-CAT5	TW/NM04
C/RO-CW1F	C-CW-SC5	CW-C-SC5	RO-CW-SC5	TW/NMO3
C/RO-CW3	C-CW-TW5	CW-C-SE-SC5	RO-CW-SE5	TW/NMO-CW3
C/RO-CW-B5	C-CW-TW5F	CW-ERNA5	RO-SC/CW-SC3	TW/SC1
C/RO-MB1	C-J/CW3	CW-NMO/ERNA3	RO-SC/RO-CW3	TW/SC3
C/RO-MB3	C-J/CW-ERNA3	CW-NMO3	RO-SC/SC3	TW/SC-TW3
C/RO-MB-CW3	C-MB-SE/ CW-MB-SC3	CW-NMO4	RO-SC3	TW/TW3
C/RO-MB-SC1	C-Q/CW4	CW-NMO5	RO-SC3F	TW/TW3F
C/RO-NMO1	C-R04	CW-NMO-ERNA5	RO-SC4	TW/TW-CW3

Selected Vegetation Types for Suitable SWFL breeding habitat				
C/RO-NMO1	C-RO/B-SC3	CW-NOW5	RO-SC5	TW/TW-SC3
C/RO-SBM-SC1	C-RO/C-B-CW3	CW-RO5	RO-SC5F	TW4
C/RO-SC1	C-RO/CW3	CW-RO5F	RO-SC-B5	TW4F
C/RO-SC3	C-RO/CW-B3	CW-RO-C-SC5	RO-SC-C5	TW5
C/RO-SC3S	C-RO/CW-RO3	CW-RO-SC5	RO-SC-CW5	TW5F
C/RO-SC-CW1	C-RO/CW-RO-SC3	CW-RO-SC5S	RO-SC-SBM5	TW5-SC5
C/RO-SC-CW3	C-RO/CW-SC3	CW-SC5	RO-SC-TW5	TW-B5
C/RO-SC-SE1	C-RO/CW-TW3	CW-SC5F	RO-SE/CW3	TW-C/CW3
C/RO-SC-TW1	C-RO/RO3	CW-SC-B5	RO-TW-CW5	TW-C/CW3F
C/RO-SC-TW3	C-RO/RO-B1	CW-SC-C5	RO-TW-SE-C5F	TW-C/CW-SC3
C/RO-SE1	C-RO/RO-C3	CW-SC-RO5	SC/CW5	TW-C/SC1
C/RO-SE-CW3	C-RO/RO-CW1	CW-SC-SE5	SC/SC3	TW-C/SC3
C/RO-TW-CW1	C-RO/RO-CW3	CW-SC-TW5	SC/SC3F	TW-C/SC-CW3
C/SBM-SC3	C-RO/RO-SC3	CW-SE5	SC/SC-B3	TW-C/TW-SC3
C/SC1	C-RO/SC3	CW-SE-C5F	SC/SC-CW3	TW-C/TW-SC-CW3
C/SC3	C-RO/SC-B-TW3	CW-TW5	SC3	TW-C4
C/SC3F	C-RO/SC-C-B3	CW-TW-C5	SC4	TW-C5
C/SC-A1	C-RO/SC-CW3	J/CW3	SC4F	TW-C-CW5
C/SC-ATX3	C-RO/SC-CW-RO3	J-C/CW3	SC5	TW-C-RO/CW3
C/SC-B1	C-RO/SC-RO3	J-RO/CW3	SC5F	TW-CW4
C/SC-B3	C-RO3	NMO/CW3	SC-ATX5	TW-CW-C5
C/SC-B3F	C-RO4	NMO-CW3	SC-B5	TW-NMO4
C/SC-B-A3	C-RO-TW/SC-B3	NMO-CW4	SC-B-C5	TW-Q4
C/SC-B-C3	C-RO-TW5	NMO-CW5	SC-B-C-RO5	TW-RO/CW3
C/SC-B-RO3	C-SBM-SC5	NMO-CW5F	SC-B-CW5	TW-SC/SC-RO3
C/SC-B-SBM3	C-SC/C-SC3	NMO-CW-ERNA5	SC-B-TW5	TW-SC5
C/SC-B-SBM-NMO1	C-SC/SC3	Q/CW3	SC-C5	TW-SC-C5
C/SC-C3	C-SC/SC-NMO1	Q/NMO-CW3	SC-C-CW5	
C/SC-C3F	C-SC/SC-RO3	Q-RO/CW3	SC-C-RO5	
C/SC-CW1	C-SC4	Q-TW/NMO3	SC-C-TW5	

Table L-3.24 Vegetation Types Excluded as not Suitable for Southwestern Willow Flycatcher Breeding Habitat

Excluded Vegetation Types Not Suitable SWFL Breeding Habitat				
ATX6	C/SC-CW3S	C-SC-B5S	NMO-CW6	RO-TW-CW5S
ATX-SS5	C/SC-NMO1S	C-SC-CAT6	NMO-ERNA5	SBM5
ATX-SS6	C/SC-RO1S	C-SC-SE5S	NMO-ERNA6	SBM6
B5	C/SC-RO3S	C-SC-TW6	NMO-MH6	SBM-C6
B6	C/SC-TW-RO1S	C-SE/A4	NMO-Q4	SBM-SC5S
B-C-CW6F	C/SE1S	C-SE/NMO3S	NMO-SB5	SC/C3S
B-CW6	C/SE-A1	C-SE/SE1	NMO-SC5	SC/SC3S
B-CW-RO-C6	C/TW3S	C-SE2	OP	SC3S
B-CW-SC6	C/TW-CW3S	C-TW/SC-B3S	OW	SC5S
BD6	C2	C-TW/SC-CW3S	OW – LFCC	SC6
BD-CW6	C2S	C-TW2	OW – Rio Grande	SC6S
B-SC6	C5S	C-TW-CW6	Q/NMO3	SC-ATX6
C/ATX-SS1S	C5S	CW6	Q/RO3	SC-B5S
C/B-A-C3S	C6	CW6S	Q2	SC-B6
C/B-CW-SC3S	CAT-C6	CW-B5S	Q4	SC-C5S
C/B-SC1S	CAT-CW6	CW-B-CAT6	Q-C/NMO1	SC-C6
C/B-SC3S	C-B5S	CW-B-SC6	Q-C1	SC-C6S
C/CW1S	C-B6F	CW-C6	Q-C2	SC-C-CAT5S
C/CW3S	C-B-CW6	CW-CAT6	Q-C4	SC-CW5S
C/CW-RO1S	C-CW2	CW-C-B6	Q-J/RO3	SC-CW6
C/CW-RO3S	C-CW6	CW-ERNA6	Q-J4	SC-CW-B6
C/CW-RO-TW3S	C-CW-B6	CW-MH6	Q-NMO3	SC-HMS6
C/CW-TW-RO1S	C-CW-TW5S	CW-NMO6	Q-NMO4	SC-NMO5S
C/ERNA3	C-J2	CW-NMO-ERNA6	RIVER	SC-RO
C/MB1	C-NMO1	CW-RO5S	RO/CW3S	SC-RO5S
C/MB-SE1	C-NMO2	CW-RO6	RO/RO3S	SC-RO6
C/NMO1	C-NMO4	CW-SC6	RO/SC3S	SC-RO-B5S
C/NMO1S	C-Q/NMO1	CW-SC6S	RO6	SC-RO-C5S
C/NMO2	C-Q/NMO3	CW-SC-B6	ROAD	SC-RO-C6
C/NMO3	C-Q1	CW-SC-C6	RO-B-SC5S	SC-SBM5S
C/NMO4	C-Q4	ERNA6	RO-C/RO-CW3S	SC-SE-RO
C/NMO-HMS-SC1S	C-RO	ERNA-CW6	RO-C6	SC-TW5S
C/RO1S	C-RO/C-B3S	HMS-CR5S	RO-CW5S	SC-TW-CW-NMO5S
C/RO2	C-RO/C-RO-B3S	J/CW6	RO-CW6	SE/MB-TH3
C/RO3S	C-RO/CW-SC3S	J-C4	RO-CW-C5S	SE/SE-TH-HL1
C/RO-CW1S	C-RO/SC-RO3S	J-C5	RO-CW-C6	SE/TH3
C/RO-NMO-SC1S	C-RO2	J-CW6	RO-CW-SE5S	SE-MB4
C/RO-SC1S	C-RO2S	LC-C-SE4	RO-J4	SS6
C/RO-SC-TW3S	C-RO5S	MB5	RO-JUSC4	TH5
C/RO-TW3S	C-RO6	MH	RO-MB/ MB-RO-CW3S	TW6
C/SBM3S	C-RO-CW-B6	MS	RO-SBM-SC6	TW-C2
C/SC1S	C-RO-SBM-SC5S	NMO/ERNA3	RO-SC5S	TW-C-CW6
C/SC3S	C-RO-SC2	NMO4	RO-SC6	TW-CW6
C/SC-B1S	C-RO-SC-B5S	NMO5	RO-SC-C6	TW-SC5S
C/SC-B3S	C-SC/CW-B-C3S	NMO5S	RO-SE-C4	
C/SC-B-A3S	C-SC5S	NMO6	RO-SE-SC5S	

Legend for Table -3.24 and L-3.25

A = False Indigobush
ATX = Fourwing Saltbush
B = Baccharis
BD = Broom Dalea
C = Cottonwood
CAT = Cattail
CW = Coyote Willow

MB = Mulberry
NMO = New Mexico Olive
Q = Oak (*Quercas* spp.)
RO = Russian Olive
SB = Silver Buffaloberry
SBM = Screwbean Mesquite

Habitat Types or Land Feature:
LFCC = Low Flow Conveyance Channel
RI = River channel
RO = Road
OP = Open Area
OW = Open Water

ERNA = Rabbitbrush
HL = Honey Locust
HMS = Honey Mesquite
J = Juniper
JUSC = Rocky Mountain Juniper

SC = Salt Cedar
SE = Siberian Elm
SS = Sand Sage
TH = Tree of Heaven
TW = Tree Willow

Last letter on selected codes:
F = potentially suitable Flycatcher habitat
S = sparse or scattered

3.6.1.4 Impact Analysis on Southwestern Willow Flycatcher

No Action

The effects of No Action Alternative on the Endangered Southwestern willow flycatcher (SWFL) are not uniform in the Project Area as shown in **Table L-3.25**. For example, in the San Acacia Section, the No Action alternative (no diversions to LFCC) provides an annual average of 462 days of flooding in occupied SWFL territories. The average frequency of flooding of all occupied sites is 53 percent. Suitable habitat within 10 miles of occupied territories receives an annual average of 20,374 acre-days and 345 acres of inundation and flooding occurs in suitable habitat during 100% of the modeled years. The maximum consecutive non-inundation period in the 40-year period of study is 5 years under this alternative in the San Acacia Section. This alternative provides the best hydrological support to occupied SWFL sites and suitable habitat in the San Acacia Section that has the greatest number of occupied sites and largest acreage of suitable habitat within 10 miles of occupied sites.

Table L-3.25 Performance Measures for Impacts of No Action on Southwestern Willow Flycatcher

NO ACTION	SWFL HABITAT CLASS	RIO CHAMA SECTION	CENTRAL SECTION	SAN ACACIA SECTION
Mean annual days inundation at occupied sites (DAYS)	Occupied Sites	No Territories	9.5	462
Mean annual acre day inundation (ACRE-DAYS)	Suitable habitat <10 mi from core areas	11	888	20,374
Mean annual acre day inundation (ACRE-DAYS)	Suitable habitat >10 mi from core areas	21	584	3,476
Mean annual acres inundation (ACRES)	Suitable habitat <10 mi from core areas	14	33	345
Mean annual acre inundation (ACRES)	Suitable habitat >10 mi from core areas	5	22	106
40-yr freq. of inundation (%)	Occupied Sites	No Territories	17	53
40-yr freq	Suitable habitat <10 mi from core areas	90	50	100
% years dry inundation	Occupied Sites	NA	0.7	0.2
Mean duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	0.3	0.8	0.2
Mean duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	0.4	0.5	0.1
40-yr freq	Suitable habitat >10 mi from core areas	90	50	53
Maximum duration of non-inundation years	Occupied Sites	No Territories	11	5
Maximum duration of non-inundation years	Suitable habitat <10 mi from core areas	1	5	0

NO ACTION	SWFL HABITAT CLASS	RIO CHAMA SECTION	CENTRAL SECTION	SAN ACACIA SECTION
Maximum duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	1	5	5

By contrast, the No Action alternative provides less hydrological support to the Rio Chama and Central Sections. Suitable habitat within 10 miles of occupied sites in the Rio Chama Section receives inundation during 90% of years, with an annual average of 11 acre-days of inundation. In the Central Section flooding occurs in at least one occupied SWFL sites in 17% of the years with an annual average of 9.5 days of flooding in occupied sites (All of the alternatives provide minimum flooding to Central Section occupied sites which range from annual averages of 9 to 39 days compared to 100 to 462 days in the San Acacia Section). Suitable habitat less than 10 miles from occupied territories in the Central Section receives an annual average of 888 acre-days of flooding during 50% of years. The maximum periods of consecutive non-inundation in occupied and nearby suitable habitat are 11 and 5 years, respectively. Overall, this alternative provides the least support of any of the alternatives to suitable habitat in the Rio Chama Section in terms of acre-days of flooding.

The overall average performance of the No Action Alternative is beneficial to the species, given the large areas of habitat supported in the San Acacia Section. It provides flows necessary to maintain and expand the population in the Middle Rio Grande SWFL recovery unit in an area with the highest population levels and most extensive suitable habitat adjacent to the possibly vulnerable occupied sites in the pool of Elephant Butte Reservoir. However, this alternative does not assist in reaching SWFL Recovery Plan goals for expanding the population by increasing the extent and duration of overbank flooding and by establishing and supporting suitable habitat in the Upper Rio Grande Unit, as described in Section 3.6.1.3.

If diversions into the LFCC would occur, overbank flooding in the San Acacia reach would be reduced by the amount shown in Figure 3.21. However, additional flows into the LFCC, up to 500 cfs, would likely improve the flycatcher habitat that currently exists in the Elephant Butte Reservoir pool. Although not quantifiable, these additional flows would also likely contribute to the expansion of suitable flycatcher habitat as more surface area is flooded. These benefits would be direct and measurable. Diversions between 500 -1000 cfs would likely provide both positive and potentially negative impacts to the occupied flycatcher habitat in the reservoir pool. Beneficial impacts would be similar to Alternative I-1 in that additional surface area would be inundated thereby providing a potential increase in suitable flycatcher habitat in the delta area. Potentially negative impacts could occur if flows were sufficiently high to cause scouring or damage to existing occupied habitat. The timing and duration of high flows would dictate the extent of adverse affect to flycatcher habitat. If existing occupied habitat were flooded for extensive periods of time, then adverse impacts to the riparian vegetation may be observed. If this were to occur, it would be over a period of time (years) and indirect. Gooding’s willow is tolerant of longer term inundation and so this potential adverse affect would be gradual and would also be dependent on other factors such as reservoir pool levels. It is quite possible that the benefits would outweigh the adverse impacts in the long-term as an increase in suitable flycatcher habitat would be the end result.

Diversions from 1000-2000 cfs could result in both beneficial and adverse impacts to occupied flycatcher habitat in the Elephant Butte Reservoir pool. Beneficial impacts would occur to a larger area, but adverse impacts could also be wider spread. Potential scouring and damage to flycatcher habitat would likely be on a larger scale, although the duration of flows possible under this alternative would not necessarily be any greater.

Mitigation of these and other adverse effects of No Action on Southwestern willow flycatcher is the subject of a 2003 Section 7 consultation with the Service entitled, “Biological Opinion on the Effects of Water and River Maintenance Operations, Army Corps of Engineers Flood Control Operations, and Related Non-Federal Action on the Middle Rio Grande, New Mexico.”

In addition, the effects of fluctuating reservoir levels at Elephant Butte to SWFLs and their habitat in the floodpool, is being addressed separately between Reclamation and the Service. None of the alternatives analyzed in this EIS would result in measurable changes to the Elephant Butte reservoir pool levels.

LFCC diversion effects on SWFL Habitat in the San Acacia Reach

The values shown in **Figure L-3.10** presented modeled floodplain inundation in the San Acacia section with no LFCC diversions. Impacts from variable levels of diversion into the LFCC (as shown in Figure 3.21) would have increasing adverse effects to flycatcher territories in the San Acacia reach, but there would be beneficial effects to territories located at the existing LFCC outfall. With LFCC diversions the average inundation would decrease by about 15% with 500cfs diversions, 30% with 1000 cfs diversions; and 57% with 2000 cfs diversions. LFCC diversions would cause long-term adverse impacts to SWFL occupied breeding sites and suitable habitat in the San Acacia sections by reducing the extent of flooding. The magnitude of effects would be directly proportional to the amount of diversions.

Action Alternative B-3

Alternative B-3 would have significant adverse impacts on Southwestern willow flycatcher averaged over the Rio Chama Section, the Central Section, and the San Acacia Section. The mean annual inundation at occupied territories and nearby suitable habitat would decrease to 29% and 46% respectively of the No Action and the 40-year frequency of inundation would decrease to 75% of No Action frequency. The maximum duration of non-inundation periods would increase from 5 to 6 years at occupied sites and from zero to 1 year at nearby suitable habitat. However, this alternative provides the most inundation to suitable habitat in the Central Section. **Table L-3.26** provides a comparison of the performance of the B-3 Alternative with No Action. Overall, this alternative ranks last among all alternatives and failure to support the hydrological needs of the flycatcher and its habitat would produce a general adverse effect that would be felt in the San Acacia Section and would result in long-term reductions in SWFL population density and failure to meet Recovery Goals for this sub-species.

Alternative B-3 would allow diversions from 1000-2000 cfs at the Low Flow Conveyance Channel, resulting in both beneficial and adverse impacts at occupied flycatcher habitat in the Elephant Butte delta area. This diversion and other aspects of the alternative produce a reservoir level approximately 10 feet higher than the No Action alternative. Beneficial impacts would occur from the additional volume of surface water available to support at the large number of occupied territories in this area. Potential scouring and damage to flycatcher habitat would likely be on a larger scale, although the duration of flows possible under this alternative would not necessarily be any greater than other Action Alternatives. The long-term benefits could outweigh the short-term impacts and would likely occur on a larger scale. These effects would also depend on the reservoir levels, since occupied flycatcher territories in this area are occasionally subject to reservoir flooding.

Selection of Alternative B-3 would likely result in significant adverse effects that could require mitigation. The differences between the impacts to SWFL in the San Acacia are related to the upstream effects as well as the effects of diversion. Due to the potential impacts of this alternative, additional studies are recommended to determine the best timing and duration of upstream storage and release as well as additional modeling to determine the full effects of LFCC diversion if this alternative is selected as the preferred alternative.

Alternative B-3 would result in an overall annual average of 1,657 acres of inundation for the San Acacia Reach, which is 2.7% greater than the annual average of 1,615 acres for No Action with the comparable LFCC diversions of 2000 cfs, as shown in **Figure L-3.32**. Alternative B-3 would result in 56.2% less inundation compared to No Action with zero diversions. Compared with No Action with similar diversions, Alternative B-3 would probably slightly increase inundation to occupied SWFL territories and suitable habitat resulting in slight long-term benefits and there could be beneficial effects to territories located at the existing LFCC outfall. However, compared with No Action with zero diversions, there could be long-term impacts. The differences between the impacts to SWFL in the San Acacia are related to the upstream effects as well as the effects of diversion. Due to the potential impacts of this alternative, additional studies are recommended to determine the best timing and duration of upstream storage and release as well as additional modeling to determine the full effects of LFCC diversion if this alternative is selected as the preferred alternative.

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Table L-3.26 Performance Measures for Impacts of ALT B-3 on Southwestern Willow Flycatcher

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative B-3
Mean annual days inundation at occupied sites (DAYS)	Occupied Sites	No Territories	37	100	
% Change from No Action with 0 diversions		NA	289.47%	-78.35%	ADVERSE
Mean annual acre day inundation (ACRE-DAYS)	Suitable habitat <10 mi from core areas	72	1010	8789	
% Change from No Action with 0 diversions		554.55%	13.74%	-56.86%	ADVERSE
Mean annual acre-day inundation (ACRE-DAYS)	Suitable habitat >10 mi from core areas	21	618	584	
% Change from No Action with 0 diversions		0.00%	5.82%	-83.20%	ADVERSE
Mean annual acres inundation (ACRES)	Suitable habitat <10 mi from core areas	6	57	224	
% Change from No Action with 0 diversions		-57.14%	72.73%	-35.07%	ADVERSE
Mean annual acre inundation (ACRES)	Suitable habitat >10 mi from core areas	1	35	29	
% Change from No Action with 0 diversions		-80.00%	59.09%	-72.64%	ADVERSE
40-yr freq. of inundation (%)	Occupied Sites	No Territories	25	40	
% Change from No Action with 0 diversions		NA	47.06%	-24.53%	ADVERSE
40-yr freq inundation (%)	Suitable habitat >10 mi from core	80	48	90	90

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative B-3
	areas				
% Change from No Action with 0 diversions		-11.11%	-4.00%	-10.00%	ADVERSE
% Years of no inundation	Occupied Sites	NA	0.7	0.2	0
% Change from No Action with 0 diversions		NA	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	0.3	0.8	0.2	0
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	0.4	0.5	0.1	0
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	85	48	30	85
% Change from No Action with 0 diversions		-5.56%	-4.00%	-43.40%	ADVERSE
Maximum duration of non-inundation years	Occupied Sites	No Territories	12	6	6
% Change from No Action with 0 diversions		NA	9.09%	20.00%	ADVERSE
Maximum duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	3	5	1	1
% Change from No Action with 0 diversions		200.00%	0.00%	0.00%	NEUTRAL
Maximum duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	1	5	11	1
% Change from No Action with 0 diversions		0.00%	0.00%	120.00%	ADVERSE
SUMMARY FINDINGS:		**BENEFICIAL**	**NEUTRAL**	**ADVERSE**	**ADVERSE**

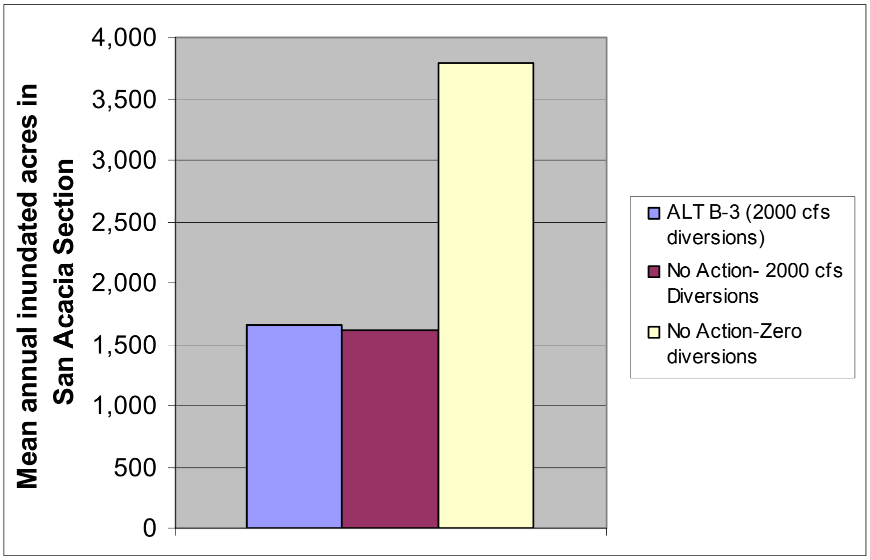

Figure L-3.32 Average annual acres of inundation in San Acacia Reach of Alternative B-3 compared with variable No Action.

Action Alternative D-3

Alternative D-3 would have significant adverse impacts on Southwestern willow flycatcher averaged over the three river sections. The mean annual inundation at occupied territories and nearby suitable habitat would decrease overall to 27% and 48% respectively from the No Action alternative. The frequency of inundation would decrease to 80% of No Action frequency. The maximum duration of non-inundation periods would increase from 5 to 6 years at occupied sites and from zero to 1 year at nearby suitable habitat. However, this alterative does provide the most inundation to suitable habitat in the Rio Chama Section. The frequency of inundation would not change significantly. **Table L-3.27** provides a comparison of the performance of the D-3 alternative with No Action. Failure to support the hydrological needs of the flycatcher and its habitat would produce a general adverse effect that would be felt in the San Acacia Section and would result in long-term reductions in SWFL population density and failure to meet Recovery Goals for this sub-species. However, this alternative could assist in reaching SWFL Recovery Plan goals for expanding the population by increasing the extent and duration of overbank flooding and establishing and supporting suitable habitat in the Upper Rio Grande Unit, as described in Section 3.6.1.3. However, compared with No Action with zero diversions, there could be long-term impacts. The differences between the impacts to SWFL in the San Acacia are related to the upstream effects as well as the effects of diversion. Due to the potential impacts of this alternative, additional studies are recommended to determine the best timing and duration of upstream storage and release as well as additional modeling to determine the full effects of LFCC diversion if this alternative is selected as the preferred alternative.

Table L-3.27 Performance Measures for Impacts of ALT D-3 on Southwestern Willow Flycatcher

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative D-3
Mean annual days inundation at occupied sites (DAYS)	Occupied Sites	No Territories	10	116	
% Change from No Action with 0 diversions		NA	5.26%	-74.89%	ADVERSE
Mean annual acre day inundation (ACRE-	Suitable habitat <10 mi from core areas	200	903	9177	

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative D-3
DAYS)					
% Change from No Action with 0 diversions		1718.18%	1.69%	-54.96%	NEUTRAL
Mean annual acre-day inundation (ACRE-DAYS)	Suitable habitat >10 mi from core areas	219	582	648	
% Change from No Action with 0 diversions		942.86%	-0.34%	-81.36%	ADVERSE
Mean annual acres inundation (ACRES)	Suitable habitat <10 mi from core areas	12	36	221	
% Change from No Action with 0 diversions		-14.29%	9.09%	-35.94%	ADVERSE
Mean annual acre inundation (ACRES)	Suitable habitat >10 mi from core areas	10	23	25	
% Change from No Action with 0 diversions		100.00%	4.55%	-76.42%	ADVERSE
40-yr freq. Of inundation (%)	Occupied Sites	No Territories	20	43	
% Change from No Action with 0 diversions		NA	17.65%	-18.87%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	75	48	90	
% Change from No Action with 0 diversions		-16.67%	-4.00%	-10.00%	NEUTRAL
% Years of no inundation	Occupied Sites	NA	0.7	0.2	
% Change from No Action with 0 diversions		NA	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	0.3	0.8	0.2	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	0.4	0.5	0.1	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	85	48	30	
% Change from No Action with 0 diversions		-5.56%	-4.00%	-43.40%	ADVERSE
Maximum duration of non-inundation years	Occupied Sites	No Territories	12	6	
% Change from No Action with 0 diversions		NA	9.09%	20.00%	ADVERSE
Maximum duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	4	5	1	
% Change from No Action with 0 diversions		300.00%	0.00%	0.00%	ADVERSE
Maximum duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	1	5	11	

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative D-3
% Change from No Action with 0 diversions		0.00%	0.00%	120.00%	ADVERSE
SUMMARY FINDINGS:		**NEUTRAL**	**NEUTRAL**	**ADVERSE**	**ADVERSE**

Alternative D-3 would result in an overall annual average of 1,571 acres of inundation for the San Acacia reach which is 2.7% less than the annual average of 1,615 acres for No Action with the comparable LFCC diversions of 2000 cfs (**Figure L-3.33**). Alternative D-3 would result in 58.5% less inundation compared to No Action with zero diversions. Compared with No Action with diversions, Alternative D-3 could slightly decrease inundation to occupied SWFL territories and suitable habitat resulting in long-term slight adverse impacts, but there could be beneficial effects to territories located at the existing LFCC outfall. However, compared with No Action with zero diversions, there could be long-term impacts. The differences between the impacts to SWFL in the San Acacia are related to the upstream effects as well as the effects of diversion. Due to the potential impacts of this alternative, additional studies are recommended to determine the best timing and duration of upstream storage and release as well as additional modeling to determine the full effects of LFCC diversion if this alternative is selected as the preferred alternative.

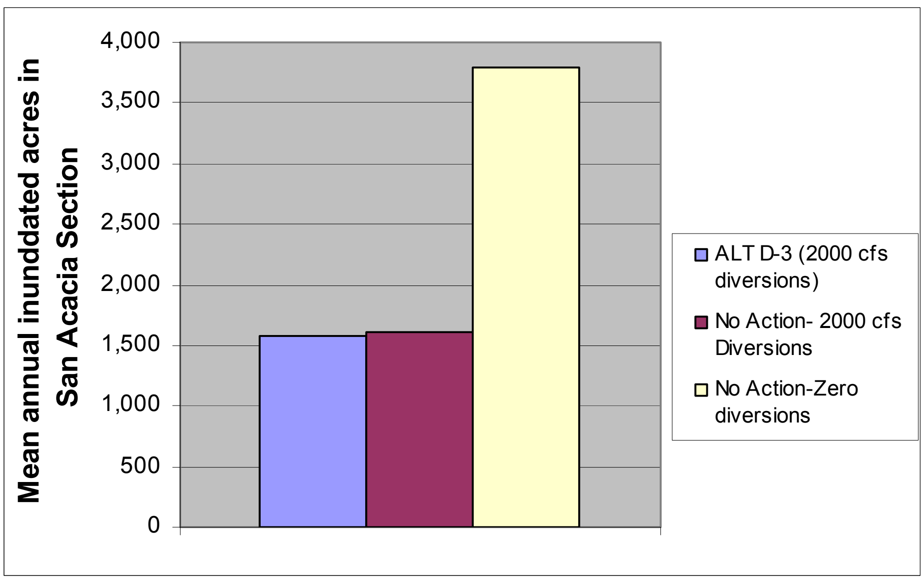

Figure L-3.33 Average annual acres of inundation in San Acacia Section of Alternative D-3 compared with variable No Action.

Action Alternative E-3

Alternative E-3 would have significant adverse impacts on Southwestern willow flycatcher averaged over the three river sections. The mean annual inundation at occupied territories and nearby suitable habitat would decrease overall to 30% and 47% from the No Action Alternative; the 40-year frequency of inundation would decrease to 72% of the No Action at occupied territories. The maximum duration of non-inundation periods would increase from 5 to 7 years at occupied sites and from zero to 1 year at nearby suitable habitat. However, this alternative does provide the most inundation at occupied sites in the Central Sections. **Table L-3.28** provides a comparison of the performance of the E alternative with No Action. Failure to support the hydrological needs of the flycatcher and its habitat would produce a general adverse effect that would be felt in the San Acacia Sections and would result in long-term reductions in

SWFL population density and failure to meet Recovery Goals for this sub-species. However, this alternative could assist in reaching SWFL Recovery Plan goals for expanding the population by increasing the extent and duration of overbank flooding and establishing and supporting suitable habitat in the Upper Rio Grande Unit, as described in Section 3.6.1.3. Selection of Alternative E-3 would likely result in significant adverse effects that could require mitigation.

Table L-3.28 Performance Measures for Impacts of ALT E-3 on Southwestern Willow Flycatcher

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative E-3
Mean annual days inundation at occupied sites (DAYS)	Occupied Sites	No Territories	39	102	
% Change from No Action with 0 diversions		NA	310.53%	-77.92%	ADVERSE
Mean annual acre day inundation (ACRE-DAYS)	Suitable habitat <10 mi from core areas	141	1063	8842	
% Change from No Action with 0 diversions		1181.82%	19.71%	-56.60%	NEUTRAL
Mean annual acre-day inundation (ACRE-DAYS)	Suitable habitat >10 mi from core areas	109	645	572	
% Change from No Action with 0 diversions		419.05%	10.45%	-83.54%	ADVERSE
Mean annual acres inundation (ACRES)	Suitable habitat <10 mi from core areas	9	63	224	
% Change from No Action with 0 diversions		-35.71%	90.91%	-35.07%	ADVERSE
Mean annual acre inundation (ACRES)	Suitable habitat >10 mi from core areas	4	40	27	
% Change from No Action with 0 diversions		-20.00%	81.82%	-74.53%	ADVERSE
40-yr freq. of inundation (%)	Occupied Sites	No Territories	23	38	
% Change from No Action with 0 diversions		NA	35.29%	-28.30%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	77	40	90	
% Change from No Action with 0 diversions		-14.44%	-20.00%	-10.00%	ADVERSE
% years of no inundation	Occupied Sites	NA	0.7	0.2	
% Change from No Action with 0 diversions		NA	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	0.3	0.8	0.2	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	0.4	0.5	0.1	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
40-yr freq inundation	Suitable habitat >10 mi	88	40	25	

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative E-3
(%)	from core areas				
% Change from No Action with 0 diversions		-2.22%	-20.00%	-52.83%	ADVERSE
Maximum duration of non-inundation years	Occupied Sites	No Territories	7	12	
% Change from No Action with 0 diversions		NA	-36.36%	140.00%	ADVERSE
Maximum duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	1	5	1	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	ADVERSE
Maximum duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	1	6	11	
% Change from No Action with 0 diversions		0.00%	20.00%	120.00%	ADVERSE
SUMMARY FINDINGS:		**NEUTRAL**	**NEUTRAL**	**ADVERSE**	**ADVERSE**

Alternative E-3 would result in an overall annual average of 1863 acres of inundation for the entire project area, which is 15.4% greater than the annual average of 1,615 acres for No Action with the comparable LFCC diversions of 2000 cfs, as shown in Figure L-3.34. This would potentially provide benefits to SWFL. However, Alternative E-3 would result in 50.8% less inundation compared to No Action with zero diversions. Compared with No Action with diversions, Alternative E-3 could increase inundation to occupied SWFL territories and suitable habitat resulting in long-term benefits and there could be beneficial effects to territories located at the existing LFCC outfall. However, compared with No Action with zero diversions, there could be long-term impacts. These differences between the impacts to SWFL in the San Acacia Section depending on the diversion to the LFCC are related to the upstream effects as well as the effects of diversion. If this alternative is selected as the preferred alternative, additional studies are recommended to determine the best timing and duration of upstream storage and release as well as additional modeling to determine the full effects of LFCC diversion.

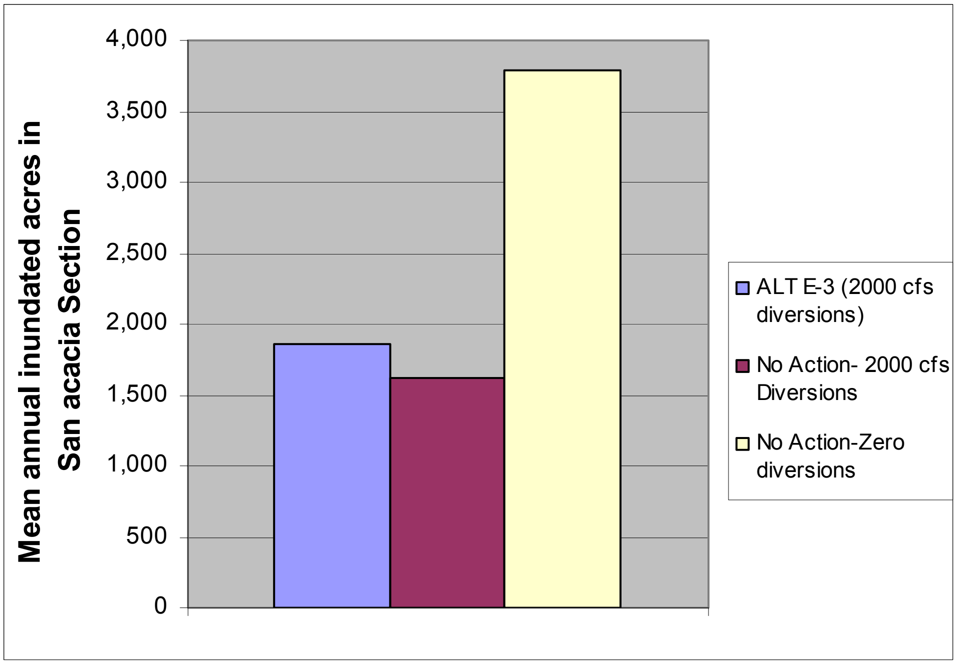

Figure L-3.34 Average annual acres of inundation in San Acacia Section of Alternative E-3 compared with variable No Action.

Action Alternative I-1

The I-1 Alternative would have the least adverse impacts on SWFL compared to the other action alternatives in the three river sections. The mean annual inundation at occupied territories and nearby suitable habitat would decrease to 85% and 88% respectively of the No Action Alternatives (within the approximate modeling error); the 40-year frequency of inundation would decrease to 95% of No Action frequency at suitable habitat near occupied territories, The maximum duration of non-inundation periods would increase from 5 to 6 years at occupied sites and from zero to 1 year at nearby suitable habitat. **Table L-3.29** provides a comparison of the performance of the I-1 alternative with No Action.

Table L-3.29 Performance Measures for Impacts of ALT I-1 on Southwestern Willow Flycatcher

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative I-1
Mean annual days inundation at occupied sites (DAYS)	Occupied Sites	No Territories	11	391	
% Change from No Action with 0 diversions		NA	15.79%	-15.37%	NEUTRAL
Mean annual acre day inundation (ACRE-DAYS)	Suitable habitat <10 mi from core areas	238	950	17615	
% Change from No Action with 0 diversions		2063.64%	6.98%	-13.54%	BENEFICIAL
Mean annual acre-day inundation (ACRE-DAYS)	Suitable habitat >10 mi from core areas	174	625	2861	
% Change from No Action with 0 diversions		728.57%	7.02%	-17.69%	BENEFICIAL

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative I-1
Mean annual acres inundation (ACRES)	Suitable habitat <10 mi from core areas	14	37	332	
% Change from No Action with 0 diversions		0.00%	12.12%	-3.77%	NEUTRAL
Mean annual acre inundation (ACRES)	Suitable habitat >10 mi from core areas	5	25	99	
% Change from No Action with 0 diversions		0.00%	13.64%	-6.60%	NEUTRAL
40-yr freq. of inundation (%)	Occupied Sites	No Territories	20	53	
% Change from No Action with 0 diversions		NA	17.65%	0.00%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	90	53	95	
% Change from No Action with 0 diversions		0.00%	6.00%	-5.00%	NEUTRAL
% years of no inundation	Occupied Sites	NA	0.7	0.2	
% Change from No 50 0 diversions		NA	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	0.3	0.8	0.2	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	0.4	0.5	0.1	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	93	53	53	
% Change from No Action with 0 diversions		3.33%	6.00%	0.00%	NEUTRAL
Maximum duration of non-inundation years	Occupied Sites	No Territories	12	6	
% Change from No Action with 0 diversions		NA	9.09%	20.00%	ADVERSE
Maximum duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	1	5	1	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
Maximum duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	1	5	5	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
SUMMARY FINDINGS:		**BENE-FICIAL**	**BENE-FICIAL**	**NEUTRAL**	**NEUTRAL**

The overall average performance of the I-1 Alternative is beneficial to the species, given the large areas of habitat supported in the San Acacia Section. It provides flows necessary to maintain and expand the population in the Middle Rio Grande SWFL recovery unit in an area with the highest population levels and most extensive suitable habitat adjacent to the possibly vulnerable occupied sites in the pool of Elephant Butte Reservoir. In addition, this alternative could assist in reaching SWFL Recovery Plan goals for expanding the population by increasing the extent and duration of overbank flooding and establishing and supporting suitable habitat in the Upper Rio Grande Unit, as described in Section 3.6.1.3.

Alternative I-1 allows diversion into the LFCC up to 500 cfs. Annual mean drainage flows in the LFCC from 1985-2001 ranged from 231 - 450 cfs. So, additional flows into the LFCC, up to 500 cfs above current drainage flows, would likely improve the flycatcher habitat that currently exists. Although not quantifiable, these additional flows would also likely contribute to the expansion of suitable flycatcher habitat when more surface area is flooded. These benefits would be direct and measurable.

LFCC diversion effects on SWFL Habitat in the San Acacia Reach

Alternative I-1 would result in an overall annual average of 3,758 acres of inundation for the San Acacia reach, which is 16.1% greater than the annual average of 3,236 acres for No Action with the comparable LFCC diversions of 500 cfs (**Figure L-3.35**). Alternative I-1 would result in 0.8% less inundation compared to No Action with zero diversions. Compared with No Action with diversions, Alternative I-1 could increase inundation to occupied SWFL territories and suitable habitat resulting in long-term benefits and there would be beneficial effects to territories located at the existing LFCC outfall. However, compared with No Action with zero diversions, there could be very slight or negligible long-term impacts.

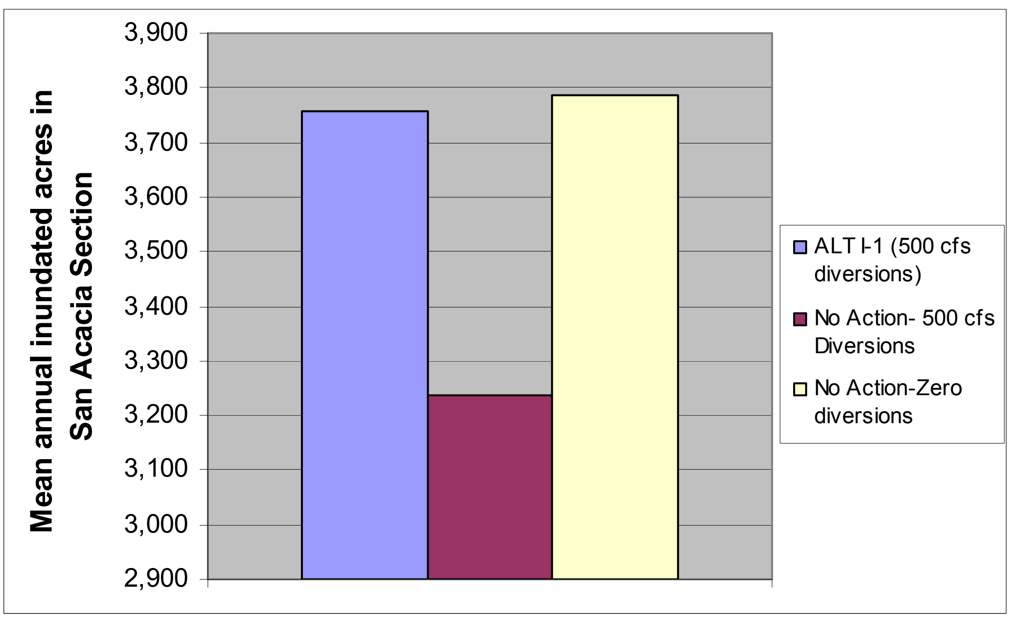

Figure L-3.35 Average annual acres of inundation in San Acacia Section of Alternative I-1 compared with variable No Action.

Action Alternative I-2

Alternative I-2 would have adverse impacts on Southwestern willow flycatcher in the San Acacia. The mean annual inundation at occupied territories and nearby suitable habitat would decrease overall to 83% and 69% of the No Action Alternative, the frequency of inundation at occupied sites would decrease to 96% of No Action frequency. The maximum duration of non-inundation periods would increase from 5 to 6 years at occupied sites and from zero to 1 year at nearby suitable habitat. The frequency of inundation would not show significant change. **Table L-3.30** provides a comparison of the performance of the I-2 alternative with No Action. Failure to support the hydrological needs of the flycatcher and its habitat would produce a general adverse effect that would be felt in the San Acacia Section and would result in long-term reductions in SWFL population density and failure to meet Recovery Goals for this sub-species. However, this alternative could assist in reaching SWFL Recovery Plan goals for expanding the population by increasing the extent and duration of overbank flooding and establishing and supporting suitable habitat in the Upper Rio Grande Unit, as described in Section 3.5.1.3.

Alternative I-2 allows diversions into the LFCC up to 1,000 cfs. Diversions between 500 -1000 cfs would likely provide both positive and potentially negative impacts to the occupied flycatcher habitat. Beneficial impacts would be similar to Alternative I-1 in that additional surface area would be inundated thereby providing a potential increase in suitable flycatcher habitat in the delta area. Potentially negative impacts could occur if flows were sufficiently high to cause scouring or damage to existing occupied habitat. The timing and duration of high flows would dictate the extent of adverse affect to flycatcher habitat. If existing occupied habitat were flooded for extensive periods of time, then adverse impacts to the riparian vegetation may be observed. If this were to occur, it would be over a period of time (years) and indirect. Gooding's willow is tolerant of longer-term inundation and so this potential adverse affect would be gradual and would also be dependent on other factors such as reservoir pool levels. It is quite possible that the benefits would outweigh the adverse impacts in the long-term as an increase in suitable flycatcher habitat would be the end result.

Table L-3.30 Performance Measures for Impacts of ALT I-2 on Southwestern Willow Flycatcher

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative I-2
Mean annual days inundation at occupied sites (DAYS)	Occupied Sites	No Territories	10	383	
% Change from No Action with 0 diversions		NA	5.26%	-17.10%	NEUTRAL
Mean annual acre day inundation (ACRE-DAYS)	Suitable habitat <10 mi from core areas	179	872	13552	
% Change from No Action with 0 diversions		1527.27%	-1.80%	-33.48%	NEUTRAL
Mean annual acre-day inundation (ACRE-DAYS)	Suitable habitat >10 mi from core areas	138	564	2,654	
% Change from No Action with 0 diversions		557.14%	-3.42%	-23.65%	NEUTRAL
Mean annual acres inundation (ACRES)	Suitable habitat <10 mi from core areas	11	34	308	
% Change from No Action with 0 diversions		-21.43%	3.03%	-10.72%	ADVERSE
Mean annual acre inundation (ACRES)	Suitable habitat >10 mi from core areas	5	23	95	
% Change from No Action with 0 diversions		0.00%	4.55%	-10.38%	NEUTRAL
40-yr freq. of inundation (%)	Occupied Sites	No Territories	20	50	
% Change from No Action with 0 diversions		NA	17.65%	-5.66%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	85	50	90	
% Change from No Action with 0 diversions		-5.56%	0.00%	-10.00%	NEUTRAL
% years of no inundation	Occupied Sites	NA	0.7	0.2	
% Change from No Action with 0 diversions		NA	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	0.3	0.8	0.2	

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative I-2
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	0.4	0.5	0.1	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	90	50	50	
% Change from No Action with 0 diversions		-5.56%	0.00%	-5.66%	NEUTRAL
Maximum duration of non-inundation years	Occupied Sites	No Territories	12	6	
% Change from No Action with 0 diversions		NA	9.09%	20.00%	**BENEFICIAL**
Maximum duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	1	5	1	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
Maximum duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	1	5	5	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
SUMMARY FINDINGS:		**BENE-FICIAL**	**NEUTRAL**	**NEUTRAL**	**NEUTRAL**

LFCC diversion effects on SWFL Habitat in the San Acacia Reach

Alternative I-2 would result in an overall annual average of 3,312 acres of inundation for the San Acacia reach, which is 23.6% greater than the annual average of 2,680 acres for No Action with the comparable LFCC diversions of 1000 cfs (Figure L-3.36). Alternative I-2 would result in 12.6% less inundation compared to No Action with zero diversions. Compared with No Action with diversions, Alternative I-2 could increase inundation to occupied SWFL territories and suitable habitat resulting in long-term benefits and there would be beneficial effects to territories located at the existing LFCC outfall. However, compared with No Action with zero diversions, there could be long-term impacts.

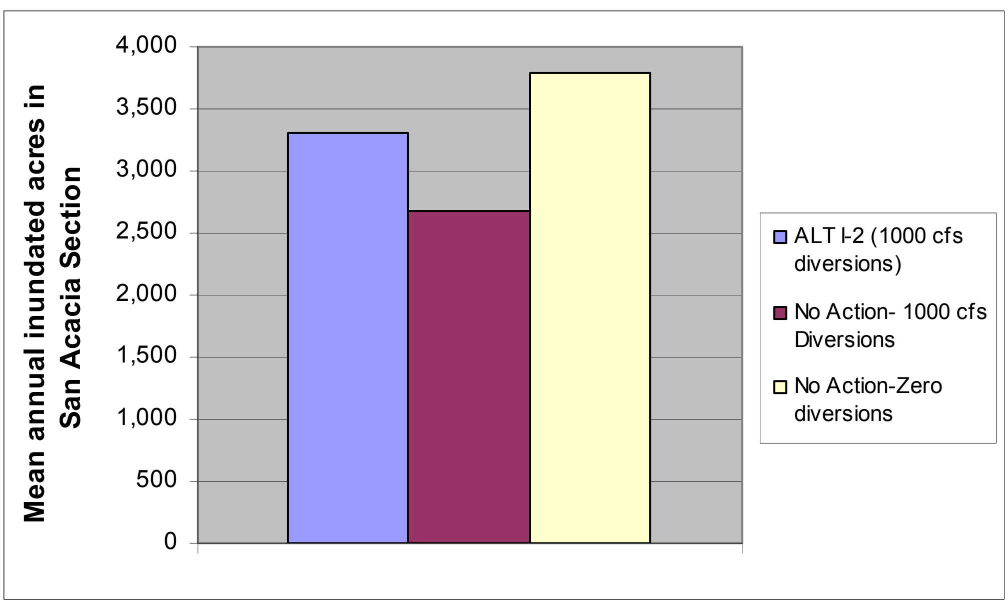

Figure L-3.36 Average annual acres of inundation in San Acacia Section of Alternative I-2 compared with variable No Action.

Action Alternative I-3

Alternative I-3 would have significant adverse impacts on Southwestern willow flycatcher averaged over the three river sections. The mean annual inundation at occupied territories and nearby suitable habitat would decrease overall to 44% and 49% respectively of the No Action alternative. The frequency of inundation at occupied sites to decrease to 91% of No Action frequency.. The maximum duration of non-inundation periods would no increase at occupied sites and increase from zero to 1 year at nearby suitable habitat. **Table L-3.31** provides a comparison of the performance of the D-3 alternative with No Action. Failure to support the hydrological needs of the flycatcher and its habitat would produce a general adverse effect that would be felt in the San Acacia Section and would result in long-term reductions in SWFL population density and failure to meet Recovery Goals for this sub-species. However, this alternative could assist in reaching SWFL Recovery Plan goals for expanding the population by increasing the extent and duration of overbank flooding and establishing and supporting suitable habitat in the Upper Rio Grande Unit, as described in Section 3.6.1.3.

Alternative I-3 would allow diversions from 1000-2000 cfs. As in Alternative I-2, both beneficial and adverse impacts would occur to occupied flycatcher habitat in the Elephant Butte delta area. The extent of inundation would be larger than in Alternative I-2. Beneficial impacts would occur to a larger area, but adverse impacts could also be wider spread. Potential scouring and damage to flycatcher habitat would likely be on a larger scale, although the duration of flows possible under this alternative would not necessarily be any greater. Impacts to flycatcher habitat would likely occur in a shorter period of time than Alternative I-2, especially if flows from the LFCC were in the higher flow range and for longer duration. As in Alternative I-2, the long-term benefits could outweigh the short-term impacts and would likely occur on a larger scale. These effects would also depend on the reservoir levels. Selection of Alternative I-3 would likely result in significant adverse effects that could require mitigation.

Table L-3.31 Performance Measures for Impacts of ALT I-3 on Southwestern Willow Flycatcher

Measure	WIFL Habitat Class	Rio Chama Section	Central Section	San Acacia Section	Overall Impact of Alternative I-3
Mean annual days inundation at occupied sites (DAYS)	Occupied Sites	No Territories	9	200	
% Change from No Action with 0 diversions		NA	-5.26%	-56.71%	ADVERSE
Mean annual acre day inundation (ACRE-DAYS)	Suitable habitat <10 mi from core areas	140	817	9,621	
% Change from No Action with 0 diversions		1172.73%	-8.00%	-52.78%	NEUTRAL
Mean annual acre-day inundation (ACRE-DAYS)	Suitable habitat >10 mi from core areas	108	527	1,392	
% Change from No Action with 0 diversions		414.29%	-9.76%	-59.95%	NEUTRAL
Mean annual acres inundation (ACRES)	Suitable habitat <10 mi from core areas	9	30	237	
% Change from No Action with 0 diversions		-35.71%	-9.09%	-31.30%	ADVERSE
Mean annual acre inundation (ACRES)	Suitable habitat >10 mi from core areas	4	20	50	
% Change from No Action with 0 diversions		-20.00%	-9.09%	-52.83%	ADVERSE
40-yr freq. Of inundation (%)	Occupied Sites	No Territories	18	48	
% Change from No Action with 0 diversions		NA	5.88%	-9.43%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	75	48	90	
% Change from No Action with 0 diversions		-16.67%	-4.00%	-10.00%	ADVERSE
% years of no inundation	Occupied Sites	NA	0.7	0.2	
% Change from No Action with 0 diversions		NA	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	0.3	0.8	0.2	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
Mean duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	0.4	0.5	0.1	
% Change from No Action with 0 diversions		0.00%	0.00%	0.00%	NEUTRAL
40-yr freq inundation (%)	Suitable habitat >10 mi from core areas	88	48	35	
% Change from No Action with 0 diversions		-2.22%	-4.00%	-33.96%	ADVERSE
Maximum duration of non-inundation years	Occupied Sites	No Territories	11	5	
% Change from No Action with 0 diversions		NA	0.00%	0.00%	NEUTRAL
Maximum duration of non-inundation (YEARS)	Suitable habitat <10 mi from core areas	4	5	1	
% Change from No Action with 0 diversions		300.00%	0.00%	0.00%	NEUTRAL
Maximum duration of non-inundation (YEARS)	Suitable habitat >10 mi from core areas	1	5	11	
% Change from No Action with 0 diversions		0.00%	0.00%	120.00%	ADVERSE
SUMMARY FINDINGS:		**NEUTRAL**	**NEUTRAL**	**ADVERSE**	**ADVERSE**

LFCC diversion effects on SWFL Habitat in the San Acacia Reach

Alternative I-3 would result in an overall annual average of 2,193 acres of inundation for the San Acacia reach that is 35.8% greater than the annual average of 1,615 acres for No Action with the comparable LFCC diversions of 2000 cfs (**Figure L-3.37**). Alternative I-3 would result in 42.1% less inundation compared to No Action with zero diversions. Compared with No Action with diversions, Alternative I-3 could increase inundation to occupied SWFL territories and suitable habitat resulting in long-term benefits and there would be beneficial effects to territories located at the existing LFCC outfall. However, compared with No Action with zero diversions, there could be long-term impacts.

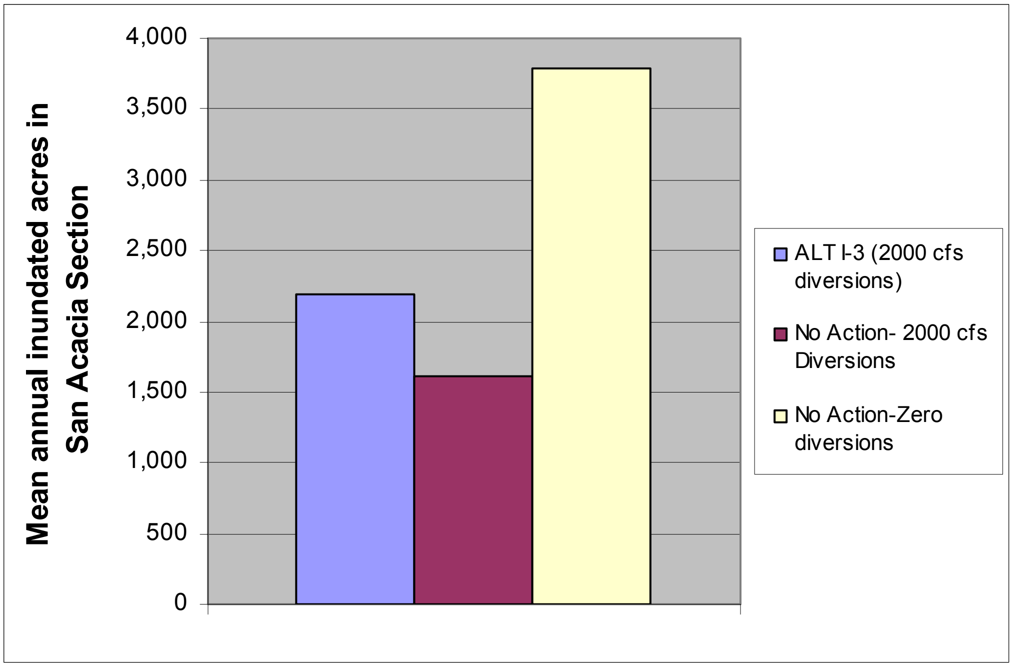

Figure L-3.37 Average annual acres of inundation in San Acacia Section of Alternative 1-3 compared with variable No Action.

3.6.1.5 Bald Eagle Impact Assessment Methods

Nesting bald eagles are only documented in a few locations in all of New Mexico, none of which are in the project area. Bald eagles occur only as winter residents within the project area. Bald eagle concentrations within the project area occur most closely associated with reservoirs along the Chama River and Middle Rio Grande. Therefore, impacts to the bald eagle were derived by qualitatively considering the potential effects to perch/roost structures and foraging habitat near known bald eagle concentration areas. For example, an assessment was made of distance between open water and perch/roost structures or foraging areas. A quantitative assessment was not conducted, due to a lack of performance measures that could be specifically tied to impacts that may affect bald eagles under the various project alternatives.

3.6.1.6 Impact Analysis on Bald Eagle

No Action

Impacts to Bald Eagle habitat can occur from decreasing the available roost sites (tall snags) near good open water habitats (foraging areas), reducing the aquatic habitat supporting the eagle's prey base, or increasing the distance from suitable roosting habitat to open water feeding areas. Bald eagles currently occur in many places along the Rio Grande, but primarily at Abiquiu and Elephant Butte reservoirs. This Project does not include operations changes at Elephant Butte Reservoir. The modeled No Action average annual reservoir elevation of Elephant Butte and Abiquiu over the 40-year period would not drastically change relative to available roosting sites. Although difficult to quantify, no change is anticipated under No Action.

Action Alternative B-3

None of the action alternatives propose water operations changes at Elephant Butte or Cochiti Reservoirs. Changes to reservoir levels at Abiquiu under Alternative B-3 would not result in significant alterations to available food supply or perching structures. Therefore, Alternative B-3 is not expected to result in adverse effects to bald eagles at the key reservoirs. While it would be difficult to detect and measure impacts to bald eagle habitat parameters in the planning area for any of the alternatives, any potential impacts to roost sites or prey base in the planning area as a result of this alternative are expected to be insignificant.

Action Alternative D-3

None of the action alternatives propose water operations changes at Elephant Butte or Cochiti Reservoirs. Changes to reservoir levels at Abiquiu under Alternative D-3 would not result in significant alterations to available food supply or perching structures. Therefore, Alternative D-3 is not expected to result in adverse effects to bald eagles at the key reservoirs. While it would be difficult to detect and measure impacts to bald eagle habitat parameters in the planning area for any of the alternatives, any potential impacts to roost sites or prey base in the planning area as a result of this alternative are expected to be insignificant.

Action Alternative E-3

None of the action alternatives propose water operations changes at Elephant Butte or Cochiti Reservoirs. Changes to reservoir levels at Abiquiu under Alternative E-3 would not result in significant alterations to available food supply or perching structures. Therefore, Alternative E-3 is not expected to result in adverse effects to bald eagles at the key reservoirs. While it would be difficult to detect and measure impacts to bald eagle habitat parameters in the planning area for any of the alternatives, any potential impacts to roost sites or prey base in the planning area as a result of this alternative are expected to be insignificant.

Action Alternative I-1

None of the action alternatives propose water operations changes at Elephant Butte or Cochiti Reservoirs. Changes to reservoir levels at Abiquiu under Alternative I-1 would not result in significant alterations to available food supply or perching structures. Therefore, Alternative I-1 is not expected to result in adverse effects to bald eagles at the key reservoirs. While it would be difficult to detect and measure impacts to bald eagle habitat parameters in the planning area for any of the alternatives, any potential impacts to roost sites or prey base in the planning area as a result of this alternative are expected to be insignificant.

Action Alternative I-2

None of the action alternatives propose water operations changes at Elephant Butte or Cochiti Reservoirs. Changes to reservoir levels at Abiquiu under Alternative I-2 would not result in significant alterations to available food supply or perching structures. Therefore, Alternative I-2 is not expected to result in adverse effects to bald eagles at the key reservoirs. While it would be difficult to detect and measure impacts to bald eagle habitat parameters in the planning area for any of the alternatives, any potential impacts to roost sites or prey base in the planning area as a result of this alternative are expected to be insignificant.

Action Alternative I-3

None of the action alternatives propose water operations changes at Elephant Butte or Cochiti Reservoirs. Changes to reservoir levels at Abiquiu under Alternative I-3 would not result in significant alterations to available food supply or perching structures. Therefore, Alternative I-3 is not expected to result in adverse effects to bald eagles at the key reservoirs. While it would be difficult to detect and measure impacts to bald eagle habitat parameters in the planning area for any of the alternatives, any potential impacts to roost sites or prey base in the planning area as a result of this alternative are expected to be insignificant.

3.6.1.7 Meadow Jumping Mouse Impact Assessment Methods

As a state-listed species (New Mexico Threatened), the meadow jumping mouse is not protected under the ESA. The mouse is, however, an extremely representative species for those utilizing marsh and wet meadow habitats. In the same manner that impacts to riparian vegetation types were used as a surrogate for assessing impacts to riparian fauna, impacts to mapped acres of marsh and salt grass/ wet meadow are used as a surrogate for effects on the meadow jumping mouse. A quantitative analysis was performed to determine potential impacts to the habitat potentially utilized by the meadow jumping mouse, as described below.

Average Annual Acre-days of Flooding in Marsh and Wet Meadow Vegetation Types

This measures the hydrological support, in extent and duration, for pertinent vegetation types. These data were obtained by GIS overlay analysis of current vegetation mapping data with the data from FLO 2-D. Specifically, annual acre days of inundation of marsh and wet meadow habitat potentially used by meadow jumping mouse populations were used as a measure to describe differences between the No Action and action alternatives. It was assumed that the baseline condition was at least maintaining extant meadow jumping mouse habitat. The impact discussion therefore discusses each Action Alternative in terms of percent change from No Action.

3.6.1.8 Impact Analysis on Meadow Jumping Mouse.

No Action Alternative

Impacts to New Mexico Meadow Jumping Mouse (meadow jumping mouse) populations would be limited to available wet meadow habitat. GIS overlay analysis indicates that the No Action alternative would support wet meadow habitats at a higher level than any of the Action Alternatives, but only by summing total acre-days throughout the Project Area. On a river section-by-section basis, No Action provides the greatest support in the San Acacia Section, is fourth for Central Section, and provides the least support of all alternatives in the Rio Chama Section (**Table L-3.32**).

Table L-3.32 Average Annual Acre-days Inundation of Potential Meadow Jumping Mouse Habitat by River Section and Alternative

Criterion	Alternative	Acre-Days Inundation			Sum	Average
		Rio Chama	Central	San Acacia		
Supports NM Meadow Jumping Mouse Habitat (Marsh & Wet Meadow)	**No Action**	5	146	9,107	9,258	3,086
	B-3	11	152	2,320	3,539	1,180
	D-3	101	141	2,573	2,815	938
	E-3	69	153	2,070	2,292	764
	I-1	114	159	7,679	7,952	2,651
	I-2	89	138	6,993	7,220	2,407
	I-3	69	127	4,190	4,386	1,462

Action Alternative B-3

Under Alternative B-3, there would be 62% less average annual acre days of inundation of marsh and marsh and wet meadow habitat potentially used by meadow jumping mouse populations. However, this Alternative performs over twice as well as No Action in the Rio Chama, representing an important increase of support for the jumping mouse because the area has limited marsh/meadow habitat. Alternative B-3 provides a slight increase in the Central Section, but approximately 75% less support for San Acacia than the No Action (**Table L-3.32**).

Action Alternative D-3

Under this alternative, there would be 70% less average annual acres days of inundation of marsh and wet meadow habitat potentially used by meadow jumping mouse populations. There is over a 200% increase for Rio Chama, slightly less for Central Section, and 72% less inundation in the San Acacia Section (**Table L-3.32**).

Action Alternative E-3

Under this alternative, there would be 75% less average annual acres days of inundation of marsh and wet meadow habitat potentially used by meadow jumping mouse populations. Alternative E-3 performs about the same as B-3, but has the poorest showing for support of meadow jumping mouse habitat in the San Acacia Section, and area where recent surveys report the species is found in all known suitable habitats (**Table L-3.31).**

Action Alternative I-1

In terms of species support, Alternative I-1 offers the best overall performance throughout the system of all alternatives. Under this alternative, there would be only 14% less average annual acres days of inundation of marsh and wet meadow habitat potentially used by meadow jumping mouse populations. This alternative provides the highest support for meadow jumping mouse habitat in the Rio Chama Section; a 226% increase over No Action. There is a slight increase (9 percent) in the Central Section, the best support offered mouse habitat by any alternative. There is only a 16% decrease over No Action in the San Acacia Section, the second best performance of all alternatives (**Table L-3.31**).

Action Alternative I-2

Under this alternative, there would be 22% less average annual acres days of inundation of marsh and wet meadow habitat potentially used by meadow jumping mouse populations. This alternative is in second place amongst all Action Alternatives. Compared to No Action, it provides about 220% greater support in the Rio Chama, slightly less (9 percent) in the Central Section, and about 75% to the San Acacia Section (**Table L-3.32**).

Action Alternative I-3

This alternative performs essentially identical to Alternative I-2, though in proportionately smaller support for jumping mouse habitat in each river Section. There would be 52% less average annual acres days of inundation of marsh and wet meadow habitat potentially used by meadow jumping mouse populations. Alternative I-3 shows the poorest support in the Central Section, where surveys show the jumping mouse has begun habitation of ditches and irrigation waterways adjacent to agricultural lands, perhaps because of dwindling acreage of preferred habitat. This alternative may contribute to the downward trend of suitable habitat in the Central Section (**Table L-3.31**).

To summarize impacts to New Mexico meadow jumping mouse habitat, while the No Action provides the greatest hydrological support to meadow jumping mouse habitat in the San Acacia Section, it would have serious adverse impacts on required habitat types in the Rio Chama, providing only 5 average annual acre-days of inundation. This is only 4% of the support offered by the best Action Alternative and less than half the support of the worst Action Alternative for that river section. Alternative I-1 performs best of all the Action Alternatives, offering a fairly well-balanced support throughout the Project Area. All other action alternatives show a negative percent change from No Action that ranges from -22% to -75 percent.

3.6.1.9 Impacts to Hydrological Variability and Adaptive Flexibility

Methods

Proposed new operations would change the flexibility of the system but do not offer a set of operating rules by which those flexibilities would by used. In order to measure the potential variability of new proposed operations, the spring peak flow of the 40-year model was investigated for differences among the alternatives and the No Action. Only one representative gage in each section was used: the Chamita gage for the Rio Chama Section, the Central gage for the Central Section, and the San Acacia gage for the San Acacia Section. Data were not available for different diversions to the LFCC in the San Acacia Section. The coefficient of variation was calculated for each alternative and river section. The coefficient of variation expresses sample variability relative to the mean of the sample.

Impacts Analysis for Peak Flow Variability and Operational Flexibility
The Peak flow of the 40-year model was investigated for differences among the alternatives and the No Action using only one representative gage in each section, the Chamita gage for the Rio Chama Section, the Central gage for the Central Section, and the San Acacia gage for the San Acacia Section. Data were not available for different diversions to the LFCC in the San Acacia Section. The coefficient of variation was calculated for each alternative and river section (**Table L-3.33**).

Table L-3.33 Coefficient of variation of peak flow magnitude, by section and alternative

Mean Peak Flow Magnitude		Rio Chama Section	Central Section	San Acacia Section
Measure	*Gage:*	*Chamita*	*Central*	*San Acacia*
Sample Size	ALL	40	40	40
Mean	B-3	1818	3880	1956
	D-3	2047	3771	1879
	E-3	1965	4041	2108
	I-1	2076	3882	2799
	I-2	2076	3882	2778
	I-3	1973	3732	1793
	No Action	2228	3989	3906
Standard Deviation	B-3	495	2187	1825
	D-3	649	1919	1574
	E-3	580	2351	1988
	I-1	575	1891	1806
	I-2	575	1891	1798
	I-3	595	1894	1581
	No Action	521	1868	1781
Coefficient of Variation	B-3	27	56	93
	D-3	32	51	84
	E-3	30	58	94
	I-1	28	49	65
	I-2	28	49	65
	I-3	30	51	88
	No Action	23	47	46

Variation of the peak flow is consistently lowest for the No Action Alternative. The effect of low variability would be to entrench and narrow the river channel and allow vegetation to encroach into the floodway. Rivers with low variability generally develop reduced riparian diversity over time (Kozlowski 2002). Alternative D-3 provides the highest variability in the Rio Chama Section, significantly higher than the No Action Alternative. Alternative E-3 provides the highest peak flow variation for both the Central and San Acacia Sections, at statistically significant levels as compared to the No Action.

Flexibility would be provided by operations with high coefficient of variability coupled with high available storage options at Abiquiu in order to augment downstream flows for conservation purposes.

This is demonstrated in the comparison of alternatives for low flow augmentation (**Figure L-3.7**) and maximum peak flow magnitude variability (**Table L-3.32**). Alternative B-3 performs highest for total available upstream storage under low flow conditions, but is less flexible for downstream delivery during years with highest peak flow volume. Alternatives D-3, E-3, and I-3 provide the greatest flexibility.

3.6.1.10 Summary of Impacts To Biological Resources

Although the goal of developing river operations that would more effectively support all biological resources in the Upper Rio Grande is a good one, many of the biological goals of a dynamic river system are seemingly at odds with one another. High levels of hydrological variability and high magnitude and duration of peaks flows can lead also to vegetation disturbance, periodic intermittency and low flow years, and other adverse effects.

Furthermore, it would be desirable to have river operations aid in the correction of long-term trends such as increase of non-native species and river aggradation/degradation, but the degree of water resource allocation to accomplish these goals must be weighed against the biological benefits of stability and seasonal predictability in a water limited system.

The relative weights assigned to the various resource categories (**Table L-3.1**) assisted the Biological Team in compiling the results of the numerous tests and impact evaluation methods into a single matrix of biological impacts of the Action Alternatives. This resulting impact matrix appears in **Table L-3.34**.

The overwhelming result of the biological studies of relative impacts is that the current river operations, as represented in the No Action Alternative without diversions to the LFCC, performed favorably for most measures of biological importance in all Sections. This result is surprising in light of many publications and studies that implicate the effects of river operations as the primary factor leading to signs of ecosystem function, such as the observed declines in native vegetation and native fish and wildlife and the presence of endangered species.

The worst performing aspect of the No Action Alternative is the possible future diversion of water to the LFCC without the possibility of increasing channel capacity or upstream storage to mitigate low flow years or enhance flow variability to offset adverse impacts in the San Acacia Section. The No Action Alternative would continue to have adverse effects to riparian vegetation in the Rio Chama Section.

Based on the relative weights assigned to each resource indicator in this study, Alternative I-2 demonstrates the best overall biological performance among all the action alternatives. This alternative provides upstream storage at intermediate levels, increases channel capacity, and provides intermediate levels of diversion to the LFCC. The effect of these changes would provide significant improvements to riparian vegetation in the Rio Chama Section while providing similar levels of support for native-dominated floodplain vegetation, faunal diversity, wetlands, and SWFL habitats in the Central and San Acacia sections.

Adverse effects in the San Acacia Section would occur with this alternative from diversion of 1,000 cfs to the LFCC. Effects would be felt compared to the current operations, as described by the No Action Alternative without diversions to the LFCC. These would consist of reduced area of RGSM habitat, decreased inundation in native vegetation types, decreased inundation in SWFL occupied and nearby suitable habitats, and reduced wetland support in the Rio Chama Section. However, this alternative performed at a similar level to No Action with equal diversions for most biological measures including endangered species habitat support and wetland support, and has the flexibility to use upstream stored water to buffer biological systems from the effects of multi-year drought.

1 **Table L-3.34 Selection Matrix for Best Biological Action Alternative by Section and Resource Category**

Biological Resource	Guiding Objective	Best Performing Action Alternative by Section and Resource			Best Action Alternative and Relative Impacts (Overall Best Biological Alternative by Resource Category)
		Rio Chama Section	Central Section	San Acacia Section	
Riverine Habitats	Supports river channel habitats	I-1	I-1	I-2	I-2 — Potential impacts include significant loss of some types of aquatic habitat in all Sections, reduced Magnitude and duration of peak flow compared to No Action.
River Sport Fish	Supports river sport fish populations	I-1	I-1	I-1	I-1 — Potential impacts include reduced channel catfish habitat compared to No Action.
Reservoir Sport Fish	Supports reservoir sport fish populations	I-1	I-1	I-1	I-1 — Potential impacts include decreased reservoir productivity in Abiquiu Reservoir compared to No Action.
Riparian Habitats	Provides vegetation structural and compositional diversity	I-2	I-1	I-2	I-2 — Potential impacts include decrease in overbank flooding in some areas compared to No Action.
Wetlands	Maintains or improves wetlands function at existing sites	I-1	I-1	I-2	I-2 — Potential impacts include decreased flows at 75th percentile and lower groundwater at some wetland sites compared to No Action.
Threatened & Endangered Species	Maintains or improves T&E [species] habitat	I-1	I-2	I-2	I-2 — Potential impacts include no inundation in currently occupied and suitable habitats for SWFL and decreased available habitat for RGSM in all river se ctions.
Aquatic and Riparian Fauna	Supports fish and wildlife diversity	I-1	I-1	I-2	I-2 — Potential impacts include decreased longnose dace habitats and decreased inundation to riparian habitats compared to No Action in the San Acacia Section.
Natural Management Areas	Supports goals of designated natural management areas	I-1	I-1	I-2	I-1 — Potential impacts include increased low flow days in Central and San Acacia Sections.
Adaptive Flexibility	Conservation storage and other flexibilities	B-3	B-3	B-3	B-3 — Potential reduction of available habitat for longnose dace and other aquatic species. Adverse effects to riparian habitats in all sections.
Instream and Overbank hydrologic variability	Flow variability	D-3	E-3	E-3	E-3 — Potential impacts include the greatest flexibility by operations with high coefficient of variability coupled with high available storage options at Abiquiu in order to augment downstream flows for conservation purposes.

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4.0 RECOMMENDATIONS AND MITIGATION MEASURES

4.1 *Recommendations and Best Management Practices for Biological Resources*

Operational flexibility exists within all Action alternatives in the timing and quantity of release of native water stored at Abiquiu Reservoir and in the timing and actualized maximum diversion of water into the Low Flow Conveyance Channel at San Marcial. All possible operations at these facilities could not be completely modeled for effects, but recommendations can be provided that will help guide possible future actions to minimize effects to aquatic resources, including the endangered Rio Grande silvery minnow.

The timing and duration of release of stored native water proposed in the Project are not specified by the Alternatives. The specific management plan would have very important consequences for biological resources. Reservoirs can be managed in a manner that provides additional support during crucial annual events such as the spring growing season. Increased flow would augment establishment and regeneration of native riparian vegetation. Note such flows must be regulated based on both channel and levee capacity. Specific recommendations and best management practices for the release of stored water include:

- Release stored native water during low flow periods to assist in maintaining target flows at levels specified in the Biological Opinion of 2003, or other Biological Opinions then in effect.
- Release conservation storage to minimize the number of number of days <100 cfs at San Marcial gage when BO targets cannot be achieved.
- Release stored native water during May and June to augment peak flow to >5,000 cfs at Albuquerque gage to achieve improved nursery habitat for RGSM and recruitment of native vegetation through overbank flooding.
- Release stored native water during May and June to increase the duration of peak flows >3,000 cfs at Albuquerque gage to provide important biological signals for fish spawn.
- Avoid release of stored native water from November to March in order to maximize potential available storage for conservation releases during Spring runoff.
- Allow passage of “flow spikes” to maximize flow variability.

The timing of diversions to the LFCC could reduce or eliminate some potentially adverse effects from Action Alternatives. Diversion of water to the LFCC does not produce effects during low flow years since a constant flow of 250 cfs must be in the channel before any additional water is diverted. It may, however, produce adverse effects to biological resources by reducing the peak discharge during Spring runoff. This reduces the amount of overbank flooding needed for native vegetation regeneration and available nursery habitat for aquatic species in the flooded overbank areas on the main stem of the Rio Grande. It also reduces variability in flow spikes used as biological signals by aquatic species. The amount of impact depends on the duration and quantity of Spring runoff. Best Management Practice for biological resources in this area would avoid operation of the LFCC during the months of May and June during any year in which such diversions would reduce the maximum area of overbank flooding in the San Acacia Section by more than 10% of the amount that would be expected without diversion.

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November 17, 2005

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Albuquerque, New Mexico 87102

Re: Upper Rio Grande Basin Water Operations (URGWOPs) Review and Water Operations Environmental Impact Statement (EIS) Draft Fish and Wildlife Coordination Act Report.

The attached draft Fish and Wildlife Coordination Act report (CAR) was prepared by the U.S. Fish and Wildlife Service for the Upper Rio Grande Water Operations Review and Water Operations Environmental Impact Statement. The CAR provides project-related information and recommendations for the protection of fish and wildlife resources.

This CAR has been prepared under the authority of and in accordance with the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661-667e). If you have any questions, please contact Mike Buntjer at (505) 346-2525, ext. 4733.

Joy E. Nicholopoulos
For
Brian Hanson
Acting Field Supervisor

Attachment

cc: (w/ atch)
Director, New Mexico Department of Game and Fish, Santa Fe, New Mexico

Draft Fish and Wildlife Coordination Act Report
for the
Upper Rio Grande Water Operations Review and Environmental Impact Statement
Colorado, New Mexico, and Texas

Submitted to:
U.S. Army Corps of Engineers
Albuquerque, New Mexico

U.S. Bureau of Reclamation,
Albuquerque, New Mexico

New Mexico Interstate Stream Commission
Albuquerque, New Mexico

Prepared by:
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November 2005

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INTRODUCTION

This is a draft Fish and Wildlife Coordination Act Report (CAR) for the Upper Rio Grande Water Operations Review (URGWOPs) and Environmental Impact Statement (EIS) prepared by the U.S. Fish and Wildlife Service (Service) under the authority of and in accordance with the requirements of Section 2(b) of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 USC 661-667e). This report addresses the URGWOPs alternatives developed by the U.S. Army Corps of Engineers (Corps), U.S. Bureau of Reclamation (Reclamation), and the New Mexico Interstate Stream Commission (NMISC). This report describes existing fish and wildlife resources in the project area, potential project impacts to fish and wildlife resources, and recommendations to avoid, minimize, and/or mitigate the potential adverse effects to fish and wildlife resources.

The Corps, Reclamation, and NMISC are conducting a review of their joint water storage and delivery operations of Federal dams, reservoirs, and other Federal facilities in the upper Rio Grande. The project area is divided into 5 sections (including 17 reaches) of river from the headwaters in Colorado to Fort Quitman, Texas (Figure 1). The Northern Section of the project area includes: Reach 1 - Alamosa to the New Mexico state line (Lobatos Guage); Reach 2 - Platoro Dam to the Rio Grande (Conejos River); Reach 3 - New Mexico state line to Velarde; and Reach 4 - Velarde to the Rio Chama confluence. The Rio Chama Section of the project area includes: Reach 5 - Heron Dam to El Vado Dam (Rio Chama); Reach 6 - El Vado Dam to Abiquiu Dam (Rio Chama); Reach 7 - Abiquiu Dam to the Rio Grande confluence; Reach 8 - Rio Grande/Chama confluence to Otowi Guage; and Reach 9 - Otowi Guage to Cochiti Dam. The Central Section of the project area includes: Reach 10 - Cochiti Dam to Bernalillo; Reach 11 - Jemez Dam to Rio Grande confluence; Reach 12 - Bernalillo to Isleta Diversion Dam; and Reach 13 - Isleta diversion to Rio Puerco confluence. The San Acacia Section includes Reach 14 - Rio Puerco confluence to Elephant Butte Reservoir. The Southern Section of the project area includes: Reach 15 - Elephant Butte Reservoir to Caballo Dam; Reach 16 - Caballo Dam to El Paso; and Reach 17 - El Paso to Fort Quitman, Texas.

The purpose of the URGWOPs EIS is to: 1) identify the operational flexibility of Federal reservoirs and facilities in the upper Rio Grande basin that are within the existing authorities of the Corps, Reclamation, and the NMISC; 2) develop a better understanding of how these facilities could be operated more efficiently and effectively as an integrated system; 3) formulate a plan for future water operations at these facilities that is within the existing authorities of the Corps, Reclamation, and NMISC; 4) comply with State, Federal, and other processes for making decisions about water operations through better interagency communications and coordination, and facilitation of public review and input; and 5) support Corps, Reclamation, and NMISC compliance with applicable law and regulations, including but not limited to, the National Environmental Policy Act (NEPA) of 1969, and the Endangered Species Act (Act) of 1973, as amended.

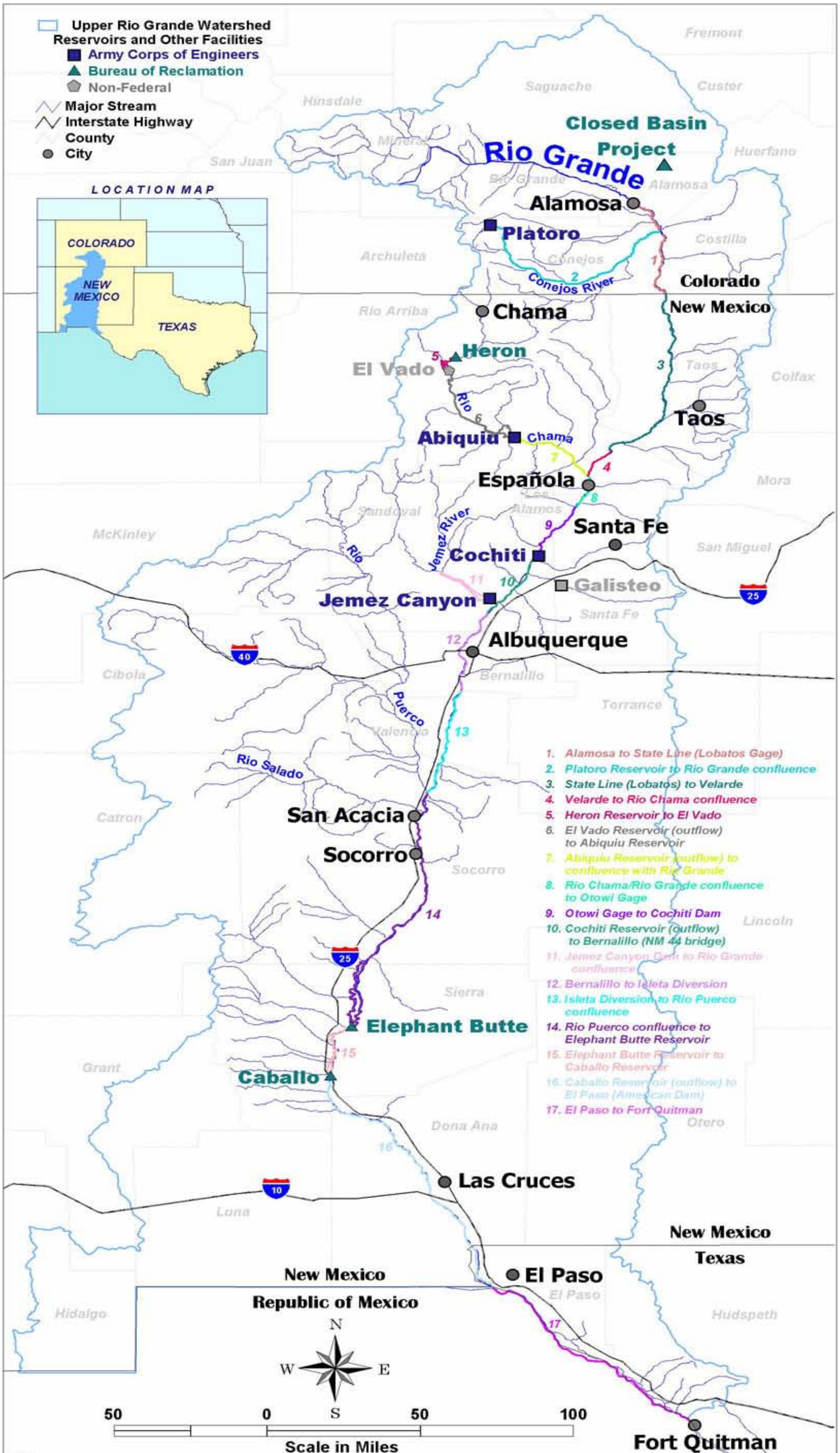

Figure 1. URGWOPs study area (from URGWOPs TeamLink website, July 2004)

DESCRIPTION OF PROJECT AREA

The Rio Grande is the fifth longest river in North America and one of the most ecologically degraded (Fullerton and Batts 2003). It originates in the San Juan Mountains of southern Colorado and flows south through New Mexico, then southeast along the border of Texas before emptying into the Gulf of Mexico at Boca Chica (Texas Natural Resource Conservation Commission 2002). In northern New Mexico, the river descends through the Rio Grande Gorge into the Española Valley, where it is joined from the northwest by the Rio Chama, its largest tributary in the project area. Flows from the Rio Chama originate from runoff in the Rio Chama watershed and from water imported from the San Juan River Basin (i.e., San Juan-Chama Project) in northwestern New Mexico. Further downstream, the river enters Cochiti Lake, which marks the northern boundary of the Middle Rio Grande Valley. From Cochiti Lake downstream to Fort Quitman, Texas, the river flows through a predominantly wide, low gradient valley.

The ancestral Middle Rio Grande developed into a single river system about 5 million years ago (Crawford et al. 1993). Incision of the Middle Rio Grande Valley has been cyclic, and has produced gravel, sand, and silt terraces 9 to 53 meters (m) (30 to 175 feet (ft)) above the current floodplain. The Rio Grande is thought to have reached maximum entrenchment between 10,000 and 20,000 years ago, at a depth 18 to 40 m (60 to 130 ft) below the current valley floor. Since that time, sediment influx from tributaries has resulted in a gradual aggradation of the river bed. Historically, this process led to frequent avulsions of the river channel. The historic river channel was braided and sinuous with a shifting sand substrate that freely migrated across the floodplain, limited only by valley terraces and bedrock outcroppings (Crawford et al. 1993).

It is believed that prior to human settlement and development the Middle Rio Grande generally supported perennial flows, although riverbed drying may have occurred in downstream areas during periods of prolonged drought (Crawford et al. 1993). Hydrographic patterns of the unregulated river would have mirrored the seasonal events of spring snowmelt and late-summer precipitation. Inputs from two tributaries in this region, the Rio Puerco and Rio Salado, were probably not perennial, but were likely more consistent than those provided by the predominantly dry riverbeds of today.

The Middle Rio Grande is the oldest continually inhabited area of the United States and the river valley has been continuously used by agricultural societies for the past 700 years. Prior to the arrival of Europeans, Pueblo farmers practiced floodwater agriculture relying on overbank flows, surface run-off, and to a limited extent, diversions from the river channel (Wozniak 1998). When Coronado’s expedition reached the Middle Rio Grande in 1540, it is estimated that 1,012 hectares (25,000 acres) of land were under cultivation. Ditch irrigation based on a network of canals and acequias became widespread with the establishment of Spanish settlements in the sixteenth and seventeenth centuries. More land in the floodplain was cleared for farming, and cottonwood forests were removed to provide timber for building material, fenceposts, and firewood. By 1850, most valley communities were established in their present locations, and by 1880 the area of irrigated land between Cochiti and San Marcial reached a maximum of about 125,000 acres (Crawford et al. 1993).

In the following decade, irrigated land use in the Middle Rio Grande dropped below 20,234 hectares (50,000 acres), until the 1930s. A combination of ecological and hydrological factors contributed to this decline. Overgrazing and deforestation of surrounding lands increased sediment loads and riverbed aggradation. This resulted in increased flooding, a higher water table, and saturation of riparian and cultivated lands. At the same time, increasing water demand upstream, particularly in the San Luis Valley of southern Colorado, decreased the supply of water for irrigation in the Middle Rio Grande. This increased the frequency of river drying in the southern reaches of the river, and supply shortages in the El Paso/Juarez area in the late 1880s and 1890s. The problems of uneven water distribution and saturation of valley lands persisted through the early stages of modern river management (Crawford et al. 1993, Middle Rio Grande Conservancy District (MRGCD) 1993).

Several small-scale water management facilities were constructed on the Middle Rio Grande prior to 1900. These structures were often unable to withstand the periodic flooding that occurred, and had to be continually repaired or replaced. The era of large-scale, federally-funded river management began shortly after the passage of the Reclamation Act in 1902. One of Reclamation's first projects after the passage of this act was constructing a dam and reservoir at Elephant Butte to serve the water needs of southern New Mexico and west Texas. Further north, the MRGCD was formed in 1925, to provide the Middle Rio Grande Valley an irrigation, drainage, and flood control system. Over the past century the various Reclamation, Corps, and MRGCD water projects transformed the Rio Grande in New Mexico into a fully managed and regulated river system. These projects and others continue to influence the hydrology, geomorphology, and fish and wildlife resources of the Rio Grande.

Major Water Management Facilities in the Project area

Several major water management facilities occur in the URGWOPs project area. These facilities include: the Closed-Basin wells; Platoro Dam; Heron Dam; El Vado Dam; Abiquiu Dam; Cochiti Dam; Jemez Canyon Dam; the Low Flow Conveyance Channel (LFCC); Elephant Butte Dam; and Caballo Dam. Although these facilities occur within the URGWOPs project area, not all of them fall within the authority of the URGWOPs EIS review.

<u>Closed-Basin Wells</u>
The Closed Basin [wells] Project (Project) was authorized by Congress in 1972 through PL 92-514, and later amended through PL 96-375 in 1980, PL 98-570 in 1984, and PL 100-516 in 1988. The Project is owned and operated by Reclamation. Management oversight is provided by a three member Operating Committee consisting of one representative from the Colorado Water Conservation Board, one from the Rio Grande Water Conservation District, and a member appointed by the Secretary of Interior. The Project's objectives include: 1) assisting Colorado in meeting annual deliveries under the Rio Grande Compact; 2) maintaining the Alamosa National Wildlife Refuge and the Blanca Wildlife Habitat Area, and stabilizing San Luis Lake; 3) allowing Colorado to apply for the reduction and elimination of any accumulated deficit in the deliveries as determined by the Rio Grande Compact Commission; and 4) providing irrigation supply and other beneficial uses in Colorado. The Project is authorized for groundwater production up to 600,000 acre-feet (ac-ft) in any consecutive ten-year period specifically to assist

Colorado in meeting annual Rio Grande Compact deliveries. Up to 5,300 ac-ft of water per year can be used for wildlife mitigation. Average annual water production is currently limited to 25,000 ac-ft due to well degradation. Although the Project is within the scope of the URGWOPs review and EIS, no operational flexibilities have been identified.

Platoro Dam and Reservoir
Platoro Dam was authorized under the Flood Control Act of 1944. The dam is owned by Reclamation, and managed by the Conejos Water Conservancy District (CWCD). The reservoir is operated for flood control and irrigation storage. The Corps monitors the flood and conservation space in a joint-use pool. If flood space is needed, then water in the conservation space is released to make room for flood inflows. Maximum releases are within the channel capacities in the Conejos River downstream (2,500 cubic feet per second (cfs)) at the Mogote gage and 1,600 cfs at the La Sauces gage). During normal operation, the CWCD maintains a 7 cfs release from October through April, and a bypass flow of 40 cfs or natural inflow whichever is less from May through September. Flood control is the only authority under review in the URGWOPs EIS for this facility.

Heron Dam and Reservoir
Heron Dam was authorized by Congress in 1962 through PL 87-483 (San Juan-Chama Transmountain Diversion Project). The reservoir is owned and operated by Reclamation to store and deliver water for irrigation, municipal, domestic, and industrial uses, and to benefit recreation and fish and wildlife resources. Up to 400,000 ac-ft (reservoir capacity) of San Juan-Chama water is stored in Heron Reservoir to provide a reliable water supply for downstream contractors. Carry-over storage of unused individual contractor water is not permitted except by the use of "waivers". A waiver allows a contractor to postpone the date in which they must take delivery of a current year's water allocation. Without the use of waivers, contractors must take delivery of their water by December 31 of each year. By using waivers, contractors can delay taking delivery of their water until April 30 of the following year. By agreement with San Juan-Chama water contractors, releases from Heron Reservoir are timed to maintain minimum winter flows below El Vado Reservoir. Winter releases follow Bureau of Land Management Rio Chama Instream Flow Assessment recommendations, and comply with the Wild and Scenic Rivers Act. The agreement also includes higher weekend releases in the summer over a six- to eight-week period to benefit whitewater rafting.

El Vado Dam and Reservoir
El Vado Dam and Reservoir were constructed by the MRGCD for flood control and irrigation (Reclamation 1983). In 1955, Reclamation rehabilitated the dam, and in 1966, constructed new outlet works to facilitate passage of additional water entering the reservoir from the San Juan-Chama Project (Reclamation 1983). El Vado Reservoir is owned by the MRGCD and operated by Reclamation under contract with the MRGCD. The reservoir's main function is irrigation storage, but the reservoir also provides incidental recreation, flood protection, sediment control, and power generation. El Vado Dam and Reservoir are not within the authority of the URGWOPs EIS review.

Abiquiu Dam and Reservoir

Abiquiu Dam was authorized for construction by the Flood Control Act of 1948, (PL 80-858) and the Flood Control Act of 1950 (PL 81-516). Construction of the dam was initiated in 1956, and the project was completed and placed into operation in 1963. The reservoir is owned and operated by the Corps primarily for flood and sediment control, but also for San Juan-Chama water supply storage, incidental recreation, and run of the river power generation. During flood control operations up to 1,800 cfs (i.e., channel capacity) is released downstream. However, releases are managed so that downstream flows do not exceed 3,000 cfs at Chamita and 10,000 cfs at the Otowi gage. Under normal operations, native water is bypassed at a rate below the downstream channel capacity. San Juan-Chama water, for Albuquerque and other contractors, is stored up to a reservoir elevation of 6,220 ft and released upon request. Voluntary water release exchanges occur between the MRGCD (at El Vado Reservoir) and Albuquerque (at Abiquiu Reservoir) to support irrigation, municipal, and industrial uses. Under normal operations efforts are made to maintain flows of 70 cfs from November through March for the trout fishery downstream of Abiquiu Reservoir. Carry-over floodwater in Abiquiu Reservoir or Cochiti Lake is held after July 1. Water is released between November 1 and March 31 when natural flow at the Otowi gage falls below 1,500 cfs.

Cochiti Dam and Lake

Cochiti Dam was authorized for construction by the Flood Control Act of 1960 (PL 86-645). The dam is owned and operated by the Corps for flood and sediment control, recreation, conservation, and development of fish and wildlife resources. During flood control operations, inflows are released as quickly possible without causing downstream flooding. During normal (non-flood control) operations, the dam passes native inflow. Carry-over floodwater in Cochiti Lake can be held after July 1, but cannot encroach upon the 212,000 acre-foot summer flood space.

Jemez Canyon Reservoir

Jemez Canyon Dam was authorized for construction by the Flood Control Act of 1948 (PL 80-858) and is owned and operated by the Corps for flood and sediment control. During flood control operations, water is released quickly without causing downstream flooding. Under current operations, the reservoir is dry and the project is operated as a run of the river facility.

Low Flow Conveyance Channel (LFCC)

The LFCC was constructed by Reclamation in the 1950s. The purpose of the LFCC is to convey Rio Grande flows downstream, improve drainage, supplement irrigation water supply, and assist New Mexico in making its downstream Rio Grande Compact deliveries. Up to 2,000 cfs can be diverted into the LFCC at San Acacia when outfall conditions allow (i.e., when the LFCC is physically capable of passing 2,000 cfs downstream into Elephant Butte Reservoir). However, diversions into the LFCC at San Acacia have not occurred since 1985 because of channel and outfall disrepair. Drainage flows in the LFCC supply the majority of the water needs at the Bosque del Apache National Wildlife Refuge, and supply the MRGCD with irrigation water. Between 2000 and 2003, drainage flows downstream of San Acacia were pumped to the river during low flows to support Rio Grande silvery minnow (*Hybognathus amarus*) (silvery minnow).

Elephant Butte Dam and Reservoir

Construction of Elephant Butte Dam was authorized in 1905 under provisions of the Newlands Act of 1902. The dam is owned and operated by Reclamation for irrigation water supply, municipal and industrial use, flood control, and recreation. It is secondarily operated for hydroelectric power generation and incidental sediment control. Elephant Butte Reservoir retains all inflows in excess of downstream irrigation demand. Releases from the dam during the irrigation season are to satisfy irrigation demand downstream of Caballo Dam and to maintain Caballo Reservoir pool levels. A 50,000 acre-foot flood control space is maintained in the reservoir from April 1 to September 30, and a 25,000 acre-foot space is maintained from October 1 to March 31. Flood control releases are required when the reservoir level is within the 50,000 acre-foot flood control space. Flood control releases are coordinated between Caballo Reservoir, upstream Corps projects, and the United States Section, International Boundary and Water Commission (IBWC). During flood control operations, maximum releases up to 5,000 cfs (downstream channel capacity) can occur. Flood control is the only authority under review in the URGWOPs EIS for Elephant Butte Dam and Reservoir.

Caballo Dam and Reservoir

Construction of Caballo Dam was authorized under the Rio Grande Rectification Treaty of 1933. Caballo Dam is owned and operated by Reclamation, however, flood control operations are directed by IBWC. The reservoir stores irrigation, municipal and industrial water, and provides flood control and incidental sediment control. During normal operations, the IBWC requires the 100,000 acre-foot flood pool to be evacuated as quickly as possible from June 1 to October 31. The reservoir retains all inflows in excess of downstream irrigation demands and the 5,000 cfs downstream channel capacity. Because of existing flood capacity, downstream target flows are 2,500 to 3,500 cfs. Reclamation and IBWC coordinate the operation of the flood control pool to ensure that flows at the American Diversion Dam downstream are maintained below 11,000 cfs. The reservoir is currently operated to maintain a storage level below 50,000 ac-ft from October 1 to January 31 to leave enough space for winter accretions. From February 1 to September 30, the reservoir is maintained within a 50,000 to 80,000 acre-foot storage level. Flood control is the only authority under review in the URGWOPs EIS for Caballo Dam and Reservoir.

PROJECT DESCRIPTION

Six action alternatives and a no action alternative are analyzed in the EIS (Table 1). The action alternatives consist of management scenarios that include: 1) adjusting waiver dates for the carry-over of stored, unused, non-permitted contract water in Heron Reservoir; 2) conserving storage of native Rio Grande water at Abiquiu Reservoir instead of releasing it downstream; and 3) Low Flow Conveyance Channel (LFCC) water diversions. The action alternatives also include modifications to the river channel capacity[1] (i.e., maximum releases during normal operations) below Abiquiu Reservoir and Cochiti Lake.

[1] The channel capacity is the normal (non-emergency) operations maximum flow in the river channel. This flow is usually set by analysis and policy and may not represent the transport capacity of the existing river channel.

Table 1. URGWOPs EIS Alternatives

Alternative	Operations
I-3	• Heron Waivers: No change-April 30 • Abiquiu conservation storage: up to 180,000 ac-ft • Abiquiu channel capacity: No change-1,800 cfs • Cochiti channel capacity: No change-7,000 cfs • LFCC water diversion: 0 to 2,000 cfs
I-2	• Heron Waivers: No change-April 30 • Abiquiu conservation storage: up to 75,000 ac-ft • Abiquiu channel capacity: No change-1,800 cfs • Cochiti channel capacity: No change-7,000 cfs • LFCC water diversion: 0 to 1,000 cfs
I-1	• Heron Waivers: No change-April 30 • Abiquiu conservation storage: up to 20,000 ac-ft • Abiquiu channel capacity: No change-1,800 cfs • Cochiti channel capacity: No change-7,000 cfs • LFCC water diversion: 0 to 500 cfs
E-3	• Heron Waivers: September 30 • Abiquiu conservation storage: up to 180,000 ac-ft • Abiquiu channel capacity: No change-1,800 cfs • Cochiti channel capacity: 10,000 cfs • LFCC water diversion: 0 to 2,000 cfs
D-3	• Heron Waivers: August 31 • Abiquiu conservation storage: up to 180,000 ac-ft • Abiquiu channel capacity: 2,000 cfs • Cochiti channel capacity: No change-7,000 cfs • LFCC water diversion: 0 to 2,000 cfs
B-3	• Heron Waivers: September 30 • Abiquiu conservation storage: up to 180,000 ac-ft • Abiquiu channel capacity: 1,500 cfs • Cochiti channel capacity: 8,500 cfs • LFCC water diversion: 0 to 2,000 cfs
No Action	• No operational changes • Heron Waivers: No change-April 30 • LFCC water diversion: 0 to 2,000 cfs

Alternative I-3

Under Alternative I-3, the existing April 30 waiver date at Heron Reservoir and the existing channel capacities below Abiquiu Reservoir and Cochiti Lake would not change. However, Alternative I-3 would include conservation storage up to 180,000 ac-ft of native Rio Grande water at Abiquiu Reservoir. According to the joint lead agencies, the release of this water would be managed to benefit fish and wildlife resources, while assisting NMISC in meeting their downstream Rio Grande Compact delivery obligations. In addition to conservation storage, Alternative I-3 would include water diversions between 0 and 2,000 cfs into the LFCC.

Alternative I-2

Under Alternative I-2, the existing April 30 waiver date at Heron Reservoir and the existing channel capacities below Abiquiu Reservoir and Cochiti Lake would not change. However, Alternative I-2 would include conservation storage up to 75,000 ac-ft of native Rio Grande water at Abiquiu Reservoir. Like Alternative I-3, the release of this water would be managed to benefit fish and wildlife resources while assisting NMISC in meeting their downstream Rio Grande Compact delivery obligations. Alternative I-2 would also include diversions into the LFCC between 0 and 1,000 cfs.

Alternative I-1

Under Alternative I-1, the existing April 30 waiver date at Heron Reservoir and the existing channel capacities below Abiquiu Reservoir and Cochiti Lake would not change. However, Alternative I-1 would include conservation storage up to 20,000 ac-ft of native Rio Grande water at Abiquiu Reservoir. Like the other action alternatives, the release of this water would be managed to benefit fish and wildlife resources while assisting NMISC in meeting their downstream Rio Grande Compact delivery obligations. Alternative I-1 would include diversions into the LFCC between 0 and 500 cfs.

Alternative E-3

Under Alternative E-3, the existing waiver date for carry-over water storage at Heron Reservoir would be changed from April 30 to September 30. Conservation storage up to 180,000 ac-ft of native Rio Grande water would be held at Abiquiu Reservoir and later released to benefit fish and wildlife resources while assisting NMISC in meeting their downstream Rio Grande Compact delivery obligations. The channel capacity below Abiquiu Reservoir would remain unchanged, however, the channel capacity below Cochiti Reservoir would increase from 7,000 to 10,000 cfs. Alternative E would also include diversions into the LFCC between 0 and 2,000 cfs.

Alternative D-3

Under Alternative D-3 the waiver date for carry-over water storage at Heron Reservoir would be changed from April 30 to August 31. Conservation storage up to 180,000 ac-ft of native Rio Grande water would be held at Abiquiu Reservoir and later released to benefit fish and wildlife resources while assisting NMISC in meeting their downstream Rio Grande Compact delivery obligations. The channel capacity below Abiquiu Reservoir would be increased from 1,800 to 2,000 cfs while the channel capacity below Cochiti Lake would remain unchanged. Alternative D-3 would also include diversions into the LFCC between 0 and 2,000 cfs.

Alternative B-3

Under Alternative B-3, the waiver date for carry-over water storage at Heron Reservoir would be changed from April 30 to September 30. Conservation storage of up to 180,000 ac-ft of native Rio Grande water would be held at Abiquiu Reservoir and later released to benefit fish and wildlife resources while assisting NMISC in meeting their downstream Rio Grande Compact delivery obligations. The channel capacity of the Rio Chama below Abiquiu Reservoir would be reduced from 1,800 cfs to 1,500 cfs. Below Cochiti Lake the channel capacity would be increased from 7,000 cfs to 8,500 cfs. Alternative B-3 would also include diversions into the LFCC of between 0 and 2,000 cfs.

No Action

The No Action Alternative would include no operational changes upstream of the LFCC, however, it would include diversions between 0 and 2,000 cfs into the LFCC at the San Acacia Diversion Dam.

EVALUATION METHODOLOGY

Since project planning began in 1998, the Service has been actively involved in the URGWOPs planning process, participating on numerous interdisciplinary teams and providing extensive verbal and written planning input to the joint lead agencies. In addition to this CAR, the Service has provided the lead agencies three Fish and Wildlife Coordination Act Planning Aid Letters (PALs). The first PAL was provided to the lead agencies on September 27, 2001, and contained a bibliography of pertinent literature related to fish and wildlife resources in the project area. The second PAL provided to the lead agencies on July 10, 2002, contained information on fish and wildlife resources in the project area, recommendations to minimize or avoid project impacts to fish and wildlife resources, and recommendations to enhance these resources. The third and final PAL, provided to the lead agencies on March 28, 2005, contained updated information on federally listed species, additional recommendations to minimize or avoid project impacts to fish and wildlife resources, and additional recommendations to enhance fish and wildlife resources in the project area.

The majority of the technical information used by the Service to evaluate project impacts to fish and wildlife resources was provided by the lead agencies. Much of this information was in the form of modeling output from the Upper Rio Grande Water Operations Model (URGWOM), Flow-2D, and Aquatic Habitat Models. Given the uncertainty of future climactic and hydrologic conditions, modeling information is the best available estimator of future change with or without the project. The modeling output provided by the lead agencies was useful not only in comparing the future with and without the project, but in predicting how baseline conditions would change over time. In addition to the technical information provided by the lead agencies, the Service also reviewed relevant project area literature.

FISH AND WILDLIFE RESOURCES WITHOUT THE PROJECT

Historic evidence of large fish species indicates that the Rio Grande was a clearer, larger, and more stable river than has been observed over the past century (Scurlock 1998). Prior to the development of Colorado's San Luis Valley in the 1870s, there were only two records of intermittent flows in the Middle Rio Grande, during prolonged and severe droughts in 1752 and 1861 (Service 2001). Over the past century, however, the Rio Grande has been consistently dewatered in the Angostura, Isleta, and San Acacia reaches, as irrigation diversions and drains have significantly reduced the overall volume of water in the river. Reaches particularly susceptible to drying in recent years include: 1) the area immediately downstream of Isleta Diversion Dam; 2) an 8-km (5-mi) reach near Tome; 3) an 8-km (5-mi) reach near the U.S. Highway 60 bridge; and 4) an extended 58-km (36-mi) reach from Brown Arroyo, downstream of Socorro, to Elephant Butte Reservoir (Service 2001).

A primary purpose of the various flood and sediment control facilities authorized under the 1948 Flood Control Act was to reverse the continuing aggradation of the river. This has largely been achieved by trapping sediment in the reservoirs, and using sediment-free reservoir releases as scouring flows to degrade (lower) the riverbed. These actions have incised the channel, increased channel capacity, reduced flood risk, and restored function to many MRGCD drains whose outfalls were formerly below the aggraded riverbed. At the same time, levees and channel modifications have constrained the river to an artificially small floodplain, reduced meandering, and produced a narrower, swifter river.

An important cumulative effect of water management activities in the project area has been to reduce the magnitude of peak spring run-off and summer thunderstorm flow events. While seasonal extremes in the river's annual flow remain present to some degree, the historic flow regime that provided a high spring peak flow leading to overbank flooding has largely been eliminated as a regular hydrological pattern (Crawford et al.1993). The current flow regime as dictated by irrigation, municipal uses, flood control, and water delivery obligations has substantially reduced the volume of peak flows and also altered their timing.

Impacts associated with the altered flow regime have been exacerbated by the use of artificial structures such as Kelner jetty jacks to control lateral migration of the river channel and artificially constrict the floodplain. A dampening of peak discharges, and subsequent decrease in sediment movement, have resulted in channel narrowing. Levee construction and channel straightening have allowed increased human development and use of the floodplain, while greatly restricting the width available to the active river channel. Between Cochiti and Elephant Butte Reservoirs, river channel surface area was reduced by roughly 50 percent between 1935 and 1989 (Crawford et al. 1993). Floodway capacity for sustained spring flows ranges from around 20,000 cfs in the Albuquerque area to around 7,500 cfs in adjacent river reaches. The channel capacity of the Rio Grande within the floodway is currently maintained by Reclamation at around 7,000 cfs (Crawford et al. 1993).

The active river channel continues to be modified, especially by the invasion of non-native plant species. Salt cedar and Russian olive have been replacing native vegetation in the Middle Rio Grande for decades. These exotic species are highly erosion-resistant, and river flows often scour the streambed rather than remove these plants. Erosion-resistant vegetation thus produces a narrower, deeper, and swifter river channel that may not provide suitable habitats for native aquatic biota. As a result of these changes, aquatic habitat characterized by sandy substrate, shallow water, and consistent low-velocity flows has diminished.

Aquatic Resources

Aquatic habitat in the Rio Grande has been altered by levees, dams, and reservoirs that store sediment and control water releases for agricultural use, flood control, recreation, and protection of development within the floodplain. Kellner jetty jack fields have straightened and channelized the river for more effective water transport. Reservoir operations have reduced peak flows and provided lower flows for a longer duration (Crawford et al. 1993). Downstream of Cochiti Dam, the altered sediment and flow regimes have resulted in the transformation from a wide, braided, sand bed system to a narrower and deeper channel with no active floodplain (Reclamation 1999). Therefore, wetlands and slack water areas are scarce (Crawford et al. 1993). The cold, clear-water releases from Cochiti Dam and the entrenched channel, armored with a gravel bed, have created an aquatic system that favors cool-water fishes and invertebrates, and limits warm water fisheries below the dam downstream to Albuquerque. Consequently, the existing aquatic resources in the project area differ from those that occurred historically due to human activities (Crawford et al. 1993).

The loss of native fish species in the project area illustrates that the hydrologic and morphological changes in the channel have had a major impact on fishery resources. The historic or pre-development ichthyofauna of the Middle Rio Grande in New Mexico is thought to have included at least 16 species (Hatch 1985, Smith and Miller 1986, and Propst et al. 1987), four of which were endemic to the region. The Phantom shiner (*Notropis orca*) and Rio Grande bluntnose shiner (*Notropis simus*) are extinct. The Rio Grande shiner (*Notropis jemezanus*) and Rio Grande speckled chub (*Extrarius aestivalis*) are extirpated from the New Mexico portion of the Rio Grande. The silvery minnow is the only native pelagic, broadcast spawning minnow surviving in the Middle Rio Grande (Bestgen and Platania 1991). A considerable number of non-native fishes have been introduced into the Rio Grande, either accidentally or as gamefish. Today, the project area contains at least 27 fish species, of which 12 are native and 15 are non-native.

Fish surveys have been conducted monthly in the project area by the Service's New Mexico Fishery Resources Office since October 1999. These surveys target the silvery minnow, but provide information on other species as well. Silvery minnows are caught consistently, but in very low numbers. Other species in the project area include brown trout, western mosquitofish, white sucker, flathead chub, fathead minnow, red shiner, gizzard shad, longnose dace, Rio Grande chub, channel catfish, small-mouth bass, white bass, common carp, and river carpsucker.

A listing of common and scientific names of fish that may occur in the Rio Grande within the project area is provided in Appendix A.

Terrestrial Resources

Vegetation

The Middle Rio Grande corridor extends through a matrix of Plains–Mesa Sand Scrub and Desert Grassland vegetation in the north, and Chihuahuan Desert Scrub in the south (Dick-Peddie 1993). Within the river floodplain, however, vegetation differs markedly from adjacent upland areas. The majority of riparian communities along the middle valley are dominated by Rio Grande cottonwood, which forms a sparse to dense canopy in the river floodplain. In areas of relatively intact native vegetation, cottonwoods sometimes share dominance with one of several native willows, particularly Gooding willow and peachleaf willow. These species may also be a major component of the understory. Other common native species in understory layers include coyote willow, New Mexico olive, skunkbush, rabbitbrush, and sandbar willow.

For cottonwoods and some willows, seed dispersal, germination, and seedling development typically take place only when the river overflows its banks and spills into the floodplain. High flows scour existing vegetation and deposit bare sediments required for the successful establishment of these species. Overbank flooding also helps facilitate vegetative reproduction of cottonwoods (Dick-Peddie 1993).

The riparian forest, or bosque, has been heavily impacted by human activities. Historically, cottonwoods were extensively harvested as fuel and building material. However, even greater impacts have resulted from twentieth-century flood control activities. Prior to human intervention, conditions necessary for cottonwood reproduction were available in most areas. Since the establishment of the levee system and flood control facilities, these conditions have become rare or non-existent. For example, the majority of cottonwoods in the Middle Rio Grande bosque today are roughly the same age, and were likely established during the last significant overbank flooding in 1941 (Crawford et al. 1993). Lack of flooding not only inhibits reproduction of cottonwoods and other native species; it also disrupts natural processes of decomposition, soil formation, and nutrient cycling. Lower river flows in general have also reduced the growth rate of established riparian vegetation. As a result, many of the Middle Rio Grande's cottonwood gallery forests are retreating, with a population of aging trees not being replaced by new growth. If these declines continue, non-native salt cedar and Russian olive will become the predominant plant species in the Rio Grande bosque (Crawford et al. 1993, Molles et al. 1998, Ellis et al. 1999).

In addition to riparian forests, other types of plant communities occur in limited areas. Sandbar communities consisting of grasses, forbs, and seedlings of cottonwood and willow exist in some locations, but are often scoured by high flows. Wetland habitats are limited in extent but present in some areas, particularly between the San Marcial railroad bridge and the delta of Elephant Butte Reservoir. Wetlands may include cattail marshes with cattail and bulrush, and wet meadows dominated by saltgrass, sedges, and young willows.

The failure of the cottonwood bosque to re-establish itself has coincided with an invasion of non-native species over the past 80 years. In many portions of the project area, cottonwood associations are being replaced by stands dominated by one or both of two fast-growing exotics: salt cedar and Russian olive. These invaders colonize the same kinds of open areas necessary for cottonwood and willow recruitment. Where not dominant, these species often form a major component of the shrubby understory. Particularly where there is no shady canopy to block sunlight, salt cedar form large, uniform stands in the floodplain. Salt cedar is most prevalent in the southern end of the Middle Rio Grande Valley, particularly in the San Acacia Reach, but extensive stands may be found throughout other portions of the project area.

Areas with dense growths of salt cedar can have major impacts on river and floodplain hydrology. Salt cedar thickets consume large amounts of water, and may locally deplete the water table. Because salt cedar is highly erosion resistant, thick stands growing alongside the river may armor river banks and contribute to river channelization. Salt cedar eradication projects have been undertaken at Bosque del Apache National Wildlife Refuge, Rio Grande Valley State Park in Albuquerque, and other locations.

Russian olive is the major exotic species in many locations in the northern part of the valley and along the Rio Chama. This species sometimes occurs in uniform stands, with few other species present, and often forms a dense understory in association with cottonwood. Other introduced species such as Siberian elm, tree-of-heaven, china-berry tree, mulberry, and black locust are found in the bosque, particularly along levee roads and in other disturbed areas. In the Corrales Bosque north of Albuquerque, Siberian elm may be poised to become the main overstory tree species as cottonwoods die off over the coming decades (Crawford et al. 1999). Suitability of non-native vegetation as habitat for native wildlife has been the subject of debate.

A listing of common and scientific names of plants that may occur in the Rio Grande floodplain within the project area is provided in Appendix B.

Mammals

Existing mammal populations are also a result of the water operations and land uses in the project area. Hink and Ohmart (1984) performed systematic floral and faunal surveys throughout the Middle Rio Grande. Residential development, agricultural conversion and subsequent irrigation systems, and construction of bridges/roads resulted in the permanent loss of habitats. Development has also caused a disruption of animal movement and dispersal patterns, and has caused continual disturbance to animal communities in the adjacent, fragmented portions of the bosque (Crawford et al. 1993). One of the largest mammals likely to occur in the project area is the coyote. Other mammals such as raccoon, beaver, muskrat, long-tailed weasel, and striped skunk may occur in the general project area. Desert cottontail rabbit, black-tailed jackrabbit, rock squirrel, pocket gopher, deer mouse, western harvest mouse, and American porcupine are also likely to occur. The most common small mammals in the Middle Rio Grande bosque are the white-footed mouse and house mouse (Stuart and Bogan 1996). Eleven species of bats are found along the Rio Grande (Findley *et al.* 1975). Two bat species are restricted to riparian areas, the Yuma myotis and little brown bat.

A listing of common and scientific names of mammals that may occur in the Rio Grande floodplain within the project area is provided in Appendix C.

<u>Birds</u>
Hink and Ohmart (1984), found that riparian areas are used heavily by most bird species in New Mexico. Cottonwood-dominated community types are highly used and are preferred habitat for many species, especially during the nesting season. Marshes, drains, and areas of open water contribute to the bird diversity of the riparian ecosystem as a whole because of the strong attraction by water-loving birds. At various times of the year, such as during migration, riparian areas support the highest bird densities and species richness in the project area. Since wetlands are scarce, reservoirs and the river in and near the project area provide habitat on a seasonal basis for a variety of waterfowl including Canada geese, mallard, gadwall, green-winged teal, American widgeon, northern pintail, northern shoveler, ruddy duck, and common merganser.

Shorebirds such as the spotted sandpiper and killdeer are likely to occur in the project area. Raptors that may occur in the project area include the bald eagle, turkey vulture, northern harrier, sharp-shinned hawk, Cooper's hawk, red-tailed hawk, American kestrel, common barn owl, and great-horned owl. Birds from a variety of habitats that may be in the project area at any given time include the common nighthawk, belted kingfisher, great blue heron, northern flicker, downy woodpecker, hairy woodpecker, violet-green swallow, northern rough-winged swallow, cliff swallow, barn swallow, black-billed magpie, common raven, plain titmouse, white-breasted nuthatch, canyon wren, western bluebird, mountain bluebird, American robin, northern mockingbird, American pipit, American dipper, European starling, yellow warbler, spotted towhee, white-crowned sparrow, red-winged blackbird, Brewer's blackbird, northern oriole and evening grosbeak (Udvardy 1977). Game species include the mourning dove, Merriam's turkey, and scaled quail.

A listing of common and scientific names of birds that may occur in the Rio Grande floodplain within the project area is provided in Appendix D.

<u>Reptiles and Amphibians</u>
Hink and Ohmart (1984) documented 3 turtle species, 17 species of lizards, and 18 snake species in the Middle Rio Grande Valley. According to Degenhardt *et al.* (1996), up to 57 species of reptiles may occur in the Middle Rio Grande Region of New Mexico. Reptiles typically found within the project area include the western collared lizard, southern prairie lizard, Great Plains skink, regal ringneck snake, desert striped whipsnake, smooth green snake, and western garter snake. The most common reptiles observed during studies in 1982 and 1983 were the plateau striped whiptail lizard and New Mexico whiptail. Thirteen amphibian species may be found in

the Middle Rio Grande Valley (Degendardt *et al.* 1996). Amphibians associated with the riparian areas such as wet meadows and marshes include chorus frogs, leopard frogs, and bullfrogs (Crawford et al. 1993). Amphibians common to all the habitat types (wetland, riparian, and upland) include the tiger salamander, Woodhouse's toad, red-spotted toad, and northern leopard frog. The most often captured or perhaps the most abundant amphibians along the Rio Grande were the bullfrog and Woodhouse’s toad (Hink and Ohmart 1984). Other species documented along the Rio Grande include Couch’s spadefoot toad, New Mexico spadefoot, red-spotted toad, and northern leopard frog (Hink and Ohmart 1984). Applegarth (1983) suggests the northern leopard frog and painted turtle were more abundant when wetlands were more numerous.

A listing of common and scientific names of reptiles and amphibians that may occur in the Rio Grande floodplain within the project area is provided in Appendix E.

Threatened and Endangered Species

Federally endangered southwestern willow flycatcher (*Empidonax traillii extimus*) (flycatcher), silvery minnow, and designated critical habitat for the silvery minnow occur in the project area. Other federally listed and candidate species occurring in the project area include the threatened bald eagle (*Haliaeetus leucocephalus*) and the candidate yellow-billed cuckoo (*Coccyzus americanus*) (cuckoo).

<u>Southwestern Willow Flycatcher</u>
The Service listed the flycatcher as endangered on February 27, 1995 (60 FR: 10693-10715). The flycatcher is also classified as endangered by the State of New Mexico (New Mexico Department of Game and Fish 1987). The current range of the flycatcher includes southern California, southern portions of Nevada and Utah, Arizona, New Mexico, western Texas, and southwestern Colorado (Unitt 1987, Browning 1993). In New Mexico, the species has been observed in the Rio Grande, Rio Chama, Zuni, San Francisco, San Juan, and Gila River drainages. Available habitat and overall numbers have declined statewide (62 FR: 39129-39147). A final recovery plan for the flycatcher was developed in 2003 (68 FR: 10485), and a final rule designating critical habitat was published on October 19, 2005 (FR 60886-61009).

Loss and modification of nesting habitat is the primary threat to this species (Phillips *et al.* 1964, Unitt 1987). Loss of migratory stopover habitat also threatens the flycatcher's survival. Large scale losses of southwestern wetlands have occurred, particularly the cottonwood-willow riparian habitats that are used by the flycatcher (Phillips *et al.* 1964, Carothers 1977, Rea 1983, Johnson and Haight 1984, Howe and Knopf 1991). The flycatcher is a riparian obligate and nests in riparian thickets associated with streams and other wetlands where dense growths of willow, buttonbush, boxelder, Russian olive, salt cedar or other plants are present. Nests are often associated with an overstory of scattered cottonwood. Throughout the flycatcher's range, these riparian habitats are now rare, widely separated by vast expanses of arid lands, and are reduced in size. Flycatchers begin arriving in New Mexico in late April and May to begin nesting and the young fledge in early summer. Flycatchers nest in thickets of trees and shrubs approximately 2 to 7 m (6.5 to 23 ft) in height or taller, with a densely vegetated understory from ground or water surface level to 4 m (13 ft) or more in height. Surface water or saturated soil is usually present beneath or next to occupied thickets (Phillips *et al.* 1964, Muiznieks *et al.* 1994). At some nest sites, surface water may be present early in the nesting season with only damp soil present by late June or early July (Muiznieks *et al.* 1994, Sferra *et al.* 1995). Habitats not selected for either nesting or singing are narrower riparian zones with greater distances between willow patches and individual willow plants. Suitable habitat adjacent to high gradient streams does not appear to be used for nesting. Areas not selected for nesting or singing may still be used during migration.

<u>Rio Grande Silvery Minnow</u>
The silvery minnow was formerly one of the most widespread and abundant fish species in the Rio Grande Basin occurring from Española, New Mexico, to the Gulf of Mexico (Bestgen and Platania 1991). This species is a moderately sized, stout minnow, approximately 9 centimeters (3.5 inches (in)) in length that spawns in the late spring and early summer, coinciding with high spring flows (Sublette *et al.* 1990). Natural habitat for the silvery minnow includes stream margins, side channels, and off-channel pools where water velocities are low or reduced from main-channel velocities. Stream reaches dominated by straight, narrow, incised channels with rapid flows are not typically occupied by silvery minnows (Sublette *et al.* 1990, Bestgen and Platania 1991).

Currently, the silvery minnow is restricted to the Middle Rio Grande in New Mexico, occurring only from Cochiti Dam downstream to the headwaters of Elephant Butte Reservoir (Platania 1991). The species was federally listed as endangered in July 1994 (59 FR: 36988-37001) and is also listed as endangered by the State of New Mexico. The Service (58 FR: 11821-11828) cited the de-watering of portions of the Rio Grande below Cochiti Dam through water regulation activities, the construction of main-stream dams, the introduction of non-native competitor/predator species, and the degradation of water quality as factors responsible for declines in the silvery minnow population. On February 19, 2003, the Service published a final rule establishing critical habitat for the silvery minnow within the last remaining portion of their historical range in the Middle Rio Grande, from Cochiti Dam to the utility line crossing the Rio Grande, a permanent identified landmark in Socorro County (68 FR: 8088-8135). The width of critical habitat along the Rio Grande is defined as those areas bound by existing levees or, in areas without levees, 91 m (300 ft) of the riparian zone adjacent to the bankfull stage of the river.

The Service determined the primary constituent elements of critical habitat for the silvery minnow based on studies of their habitat and population biology (68 FR 8088). The primary constituent elements of silvery minnow critical habitat include:

1. A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining diverse aquatic habitats (e.g., backwaters, side channels, pools, eddies, and runs). This hydrologic regime should, to the extent possible, mimic a natural hydrograph. Flows in the early spring to early summer (March through June) should create aquatic habitat complexity and trigger spawning; flows in the summer and fall (June through October) should be sufficient to maintain aquatic habitat and prevent river drying; and flows in the winter (November through February) should be relatively constant.

2. Unimpounded stretches (i.e., river miles) of river that contain a variety of habitat types (i.e., pools, backwaters, etc.) and year-round flow.

3. Silt and sand dominated substrates.

4. Suitable water quality; that is, water flowing through critical habitat should be well oxygenated (year-round) and remain in the temperature range of 1 ^{o}C (35 ^{o}F) to 30 ^{o}C (85 ^{o}F).

The primary constituent elements identified above facilitate the physiological, behavioral, and ecological requirements of the silvery minnow. The first primary constituent element provides sufficient flows to minimize the formation of isolated pools. This element is essential to the conservation of the silvery minnow because the species cannot withstand river drying. Water is a necessary component of all silvery minnow life history stages. The second primary constituent element facilitates silvery minnow reproduction and recruitment. Low-velocity habitats provide food, shelter, and nursery habitat, which are essential for the survival and recruitment of the species (68 FR 8008). The third primary constituent element, silt and sand substrates (Dudley and Platania 1997), characterize habitats that are used by the silvery minnow for foraging and shelter. The final primary constituent element provides suitable water quality necessary for silvery minnow survival.

Bald Eagle

The project area is also within the known and historic range of the bald eagle. The Service reclassified the bald eagle from endangered to threatened on July 12, 1995 (60 FR: 36000-36010). Adult bald eagles are easily recognized by their white heads and dark bodies. Wintering bald eagles frequent all major river systems in New Mexico from November through March, including the Rio Grande. This species prefers to roost and perch in large trees near water, typically cottonwoods in the project area. Prey includes fish, waterfowl, and small mammals.

Major present and foreseeable threats to the bald eagle include habitat degradation and destruction, and environmental contamination (e.g., prey base contamination). The main threats to New Mexico's wintering bald eagle population include impacts to their prey base and the availability of suitable roost sites. Between 1988 and 1996, the Corps conducted annual winter bald eagle surveys along the Rio Grande from Albuquerque, upstream to El Vado Dam. The mean annual number of bald eagle sightings during the surveys is 64, with the largest number sighted occurring in 1993 (88). Survey data show that wintering bald eagles use the habitat in the vicinity of the project for feeding, perching, and roosting (Reclamation 1999).

Yellow-billed cuckoo

The western population of the yellow-billed cuckoo has experienced a severe decline in distribution and abundance throughout the western United States. This is primarily attributed to loss, degradation, and fragmentation of riparian woodland habitats, overgrazing, and river management, including altered flow and sediment regimes, and flood control practices, such as channelization and bank protection (Laymon and Halterman 1989). On July 25, 2001, the

Service published a 12-month finding on a petition to federally list the cuckoo in the western United States under the Act. The Service found that the petitioned action was warranted, but precluded by higher priority listing actions, making the western population a candidate species. In New Mexico, the cuckoo is a candidate species in the western portion of the State, to and including the Rio Grande corridor.

The cuckoo prefers riparian habitat with dense willow, cottonwood, salt cedar and/or mesquite (Hamilton and Hamilton 1965, Gaines 1974, Walters 1983, Howe 1986, Lehman and Walker 2001). Food sources include large insects, caterpillars, katydids, cicadas, grasshoppers, crickets, frogs, lizards, bird eggs and young, fruit and seeds (Hughes 1999). Suitable breeding habitat consists of large stands of dense willow and cottonwood, but exotics like salt cedar are also used. South of Caballo Dam, nesting cuckoos were detected in Seldon Canyon along the Rio Grande (Tafanelli and Meyer 1999). These territories were located in either narrow salt cedar habitat, tall and dense salt cedar habitat, or mixed salt cedar/willow habitat. Therefore, habitat preferences of western cuckoos may be more varied than previously thought (Lehman and Walker 2001).

In New Mexico, the cuckoo was historically rare statewide, but common in riparian areas along the Rio Grande between Albuquerque and Elephant Butte Reservoir, and locally common along other New Mexico rivers. A review on the status of the species in New Mexico concluded that the species would likely experience future declines in the State due to loss of riparian woodlands (Howe 1986). Along the Rio Grande, water and flood control projects have altered flow regimes and river dynamics, inhibiting regeneration of cottonwood-willow riparian habitats. Future degradation and loss of such riparian vegetation would limit the amount of available habitat for the cuckoo (W. Howe, Service, pers., comm., 1999). Cuckoos have also been observed downstream of the San Marcial railroad bridge (Reclamation 2000).

Future Conditions Without the Project

The future conditions without the project include the affected environment with trends through the implementation period. Baseline biological conditions were projected through time to develop expected trends and future conditions.

Under the No Action Alternative, no operational changes are proposed in the Northern, Rio Chama, Central or Southern Sections of the project area. Therefore, fish and wildlife resources in these sections are expected to remain at or near their existing conditions without the project. In the Central Section, fish and wildlife resources may improve over time as a result of ongoing and proposed bosque and aquatic habitat improvement projects. In addition, the management of Jemez Canyon Reservoir as a flow-through facility should benefit fish and wildlife resources in the Central Section by increasing sediment inputs to the Rio Grande and reducing riverbed incision between the confluence of the Rio Grande and Bernalillo.

The No Action Alternative includes operational changes in the San Acacia Section that would impact fish and wildlife. According to the joint lead agencies, the future without the project would include diversions between 0 and 2,000 cfs into the LFCC at the San Acacia Diversion

Dam. These diversions would significantly impact fish and wildlife resources in and adjacent to the river in the San Acacia Section, particularly between the San Acacia Diversion Dam and the San Marcial railroad bridge. Impacts to fish and wildlife resources would include entrainment of fish and other aquatic biota into the LFCC, habitat degradation downstream of the San Acacia Diversion Dam. Diversion related impacts to fish and wildlife resources would be directly proportional to the the magnitude of flow diverted from the river. Diversions into the LFCC would further regulate or reduce the hydrograph in the San Acacia Section, increasing intermittency and diminishing natural hydrologic processes (e.g., overbank flooding, scouring, and deposition) that create and maintain diverse aquatic and riparian habitats. For example, under the No Action Alternative, flows downstream of the San Acacia Diversion Dam would be less than or equal to 250 cfs 87.5 percent of the time over the 40-year modeling period, compared to only 27.1 percent of the time without diversions. Mean flows would also decline. With diversions, mean flows downstream of the San Acacia Diversion Dam would be approximately 392.1 cfs over the 40-year modeling period, compared to 1,004.4 cfs without diversions. As a result of these hydrologic changes, aquatic and riparian habitats in the San Acacia Section would increasingly uniform and degraded. In riparian areas, highly water-consumptive, non-native vegetation such as salt cedar would have a competitive advantage over native vegetation and increasingly dominate the riparian vegetative community. As non-native vegetation proliferates, evapotranspiration rates could increase. This could result in a lowering of the water table and increase the frequency and duration of river drying, particularly in areas where monotypic salt cedar stands develop or expand.

Threatened and Endangered Species
Issues with federally listed species will be addressed in detail during section 7 consultation under the Act.

FISH AND WILDLIFE RESOURCES WITH THE PROJECT

No operational changes are proposed in the Northern or Southern Sections of the project area. Therefore, fish and wildlife resources in these sections are expected to remain at or near their existing conditions with the project. Operational changes are, however, proposed in the Rio Chama, Central, and San Acacia Sections that would impact fish and wildlife resources. The largest impacts to fish and wildlife resources would occur in the San Acacia Section, and occur as a direct result of diversions into the LFCC. Impacts associated with diversions would be similar to those described above for the No Action Alternative. Project-related impacts to fish and wildlife resources described below for the Rio Chama and Central Sections, are based on URGWOPs modeling information and include the full range of impacts anticipated. The same is true for the riparian impacts described for the San Acacia Section. Due to modeling limitations and the wide range of variability in potential diversions under each alternative (i.e., 0 to 2,000 cfs under Alternatives B-3, D-3, E-3, and I-3), the aquatic impacts described for the San Acacia Section include only those that would occur when flows in the river are sufficient to divert the maximum allowable under each alternative (i.e., up to 2,000 cfs). They do not include the impacts of the higher frequency, lower level diversions (e.g., less than 2,000 cfs) that would occur under each alternative. Thus, the impacts to aquatic resources described for the San Acacia Section are only a portion of the total impacts expected with the project.

Alternative I-3

Under Alternative I-3, the mean annual maximum acres of overbank flooding would decline by approximately 27 percent (39 acres) in the Rio Chama Section, 7 percent (19 acres) in the Central Section, and 40 percent (1,104 acres) in the San Acacia Section. In the three sections combined, the mean annual maximum acres of overbank flooding would decline by approximately 37 percent (1,162 acres).

Although the maximum extent of overbank flooding in the Rio Chama Section would be lower, the extent and duration of spring overbank flooding over the 40-year modeling period would be higher, increasing approximately 82 percent (936 acre-days). In the Central and San Acacia Sections, the extent and duration of spring overbank flooding would decline by approximately 10 percent (760 acre-days) and 54 percent (71,071 acre-days), respectively. For the three sections combined, the extent and duration of spring overbank flooding would decline by approximately 50 percent (70,895 acre-days).

Under Alternative I-3, longnose dace habitat in the Rio Chama, Central, and San Acacia Sections combined would decline by approximately 12.3 percent (102,405 square feet (ft^2)) on average, with the largest habitat losses (57.8 percent (87,333 ft^2)) occurring in the San Acacia Section. Channel catfish habitat would decline by approximately 8.1 percent (219,268 ft^2) for the three river sections impacted, with the largest habitat losses (39.9 percent, (198,403 ft^2)) occurring in the San Acacia Section. Flathead chub and river carpsucker habitat would decline by approximately 8.0 percent (91,459 ft^2)), with the largest habitat losses (40.7 percent (96,970 ft^2)) again occurring in the San Acacia Section.

Alternative I-2

Under Alternative I-2, the mean annual maximum acres of overbank flooding in the Rio Chama and San Acacia Sections would decline by approximately 15 percent (22 acres) and 10 percent (285 acres) respectively, and increase in the Central Section by approximately 3 percent (8 acres). In the three sections combined, the mean annual maximum acres of overbank flooding would decline by approximately 9 percent (299 acres).

Although the maximum extent of overbank flooding in the Rio Chama Section would be lower under Alternative I-2, the extent and duration of spring overbank flooding over the 40-year modeling period would be substantially higher, increasing by approximately 115 percent (1,313 acre-days). In the Central and San Acacia Sections, the extent and duration of spring overbank flooding would decline by approximately 3 percent (222 acre-days) and 31 percent (40,292 acre-days), respectively. For the three sections combined, the extent and duration of spring overbank flooding would decline by approximately 28 percent (39,201 acre-days).

Under Alternative I-2, longnose dace habitat in the Rio Chama, Central, and San Acacia Sections combined would decline by approximately 9.7 percent (80,483 ft^2) on average, with the largest habitat losses (45.1 percent (68,143 ft^2)) occurring in the San Acacia Section. Channel catfish habitat would decline by approximately 6.6 percent (179,149 ft^2), with the largest habitat losses (31 percent (154,122 ft^2)) occurring in the San Acacia Section. Flathead chub and river carpsucker habitat would decline by 6.8 percent (77,179 ft^2) with the largest habitat losses (32.3 percent (76,856 ft^2)) again occurring in the San Acacia Section.

Alternative I-1

Under Alternative I-1, the mean annual maximum acres of overbank flooding in the Rio Chama section would remain unchanged. However, in the Central and San Acacia Sections, it would increase by approximately 17 percent (43 acres) and 5 percent (148 acres), respectively. In the three sections combined, the mean annual maximum acres of overbank flooding would decline by approximately 3 percent (105 acres).

Although the maximum extent of overbank flooding in the Rio Chama Section would not change under Alternative I-1, the extent and duration of spring overbank flooding over the 40-year modeling period would be substantially higher, increasing by approximately 164 percent (1,867 acre-days). In the Central Section, the extent and duration of spring overbank flooding would increase by approximately 8 percent (609 acre-days). In the San Acacia Section, the extent and duration of spring overbank flooding would decline by approximately 15 percent (20,164 acre-days). For the three sections combined, the extent and duration of spring overbank flooding would decline by approximately 13 percent (17,688 acre-days).

Under Alternative I-1, longnose dace habitat in the Rio Chama, Central, and San Acacia Sections combined would decline by approximately 5 percent (41,737 ft^2) on average, with the largest habitat losses (27 percent (40,802 ft^2)) occurring in the San Acacia Section. Channel catfish habitat would decline by approximately 3.7 percent (100,632 ft^2), with the largest habitat losses (18.7 percent (92,966 ft^2)) occurring in the San Acacia Section. Flathead chub and river carpsucker habitat would decline by 3.9 percent (44,898 ft^2), with the largest habitat losses (19.7 percent (44,898 ft^2)) again occurring in the San Acacia Section.

Alternative E-3

Under Alternative E-3, the mean annual maximum acres of overbank flooding would decline by approximately 27 percent (39 acres) and 53 percent (1,464 acres) in the Rio Chama and San Acacia Sections, respectively, and increase by approximately 91 percent (236 acres) in the Central Section. Channel capacity in the Central Section would also increase from 7,000 to 10,000 cfs. In the three sections combined, the mean annual maximum acres of overbank flooding would decline by approximately 40 percent (1,267 acres).

Although the maximum extent of overbank flooding in the Rio Chama Section would decline under Alternative E-3, the extent and duration of spring overbank flooding over the 40-year modeling period would be substantially higher, increasing by 76 percent (869 acre-days). In the Central Section, the extent and duration of spring overbank flooding would increase by approximately 14 percent (1,087 acre-days). In the San Acacia Section, the extent and duration of spring overbank flooding would decline by approximately 65 percent (85,206 acre-days). For the three sections combined, the extent and duration of spring overbank flooding would decline by approximately 59 percent (83,250 acre-days).

Under Alternative E-3, longnose dace habitat in the Rio Chama, Central, and San Acacia Sections combined would decline by approximately 12.2 percent (101,506 ft^2) on average, with the largest habitat losses (57.8 percent (87,226 ft^2)) occurring in the San Acacia Section. Channel catfish habitat would decline by a total of approximately 8 percent (215,816 ft^2), with the largest habitat losses (39.7 percent (197,695 ft^2)) occurring in the San Acacia Section. Flathead chub and river carpsucker habitat would decline by 7.9 percent (90,087 ft^2), with the largest habitat losses 40.6 percent (96,667 ft^2)) again occurring in the San Acacia Section.

Alternative D-3

Under Alternative D-3, the mean annual maximum acres of overbank flooding in the Rio Chama and San Acacia Sections would decline by approximately 9 percent (13 acres) and 55 percent (1,516 acres), respectively, and increase in the Central Section by approximately 8 percent (20 acres). In the three sections combined, the mean annual maximum acres of overbank flooding would decline by approximately 48 percent (1,509 acres).

Although the maximum extent of overbank flooding in the Rio Chama Section would decline under Alternative D-3, the extent and duration of spring overbank flooding over the 40-year modeling period would be substantially higher, increasing by 132 percent (1,506 acre-days). This increase is due, in part, to the proposed increase in channel capacity from 1,800 to 2,000 cfs downstream of Abiquiu Reservoir. In the Central and San Acacia Sections, the extent and duration of overbank flooding would decrease by approximately 1 percent (40 acre-days) and 63 percent (83,309 acre-days), respectively. For the three sections combined, the mean duration of overbank flooding would decline by approximately 58 percent (81,843 acre-days).

Under Alternative D-3, longnose dace habitat in the Rio Chama, Central, and San Acacia Sections combined would decline by approximately 12 percent (100,206 ft^2) on average, with the largest habitat losses (57.8 percent (87,235 ft^2)) occurring in the San Acacia Section. Channel catfish habitat would decline by approximately 8 percent (215,060 ft^2), with the largest habitat losses (39.8 percent (198,089 ft^2)) occurring in the San Acacia Section. Flathead chub and river carpsucker habitat would decline 7.9 percent (90,148 ft^2), with the largest habitat losses (40.7 percent (96,929 ft^2)) again occurring in the San Acacia Section.

Alternative B-3

Under Alternative B-3, the mean annual maximum acres of overbank flooding would decline by approximately 53 percent (78 acres) in the Rio Chama Section and 53 percent (1,455 acres) in the San Acacia Section, and increase by approximately 78 percent (203 acres) in the Central Section. The decline in the mean annual maximum acres of overbank flooding in the Rio Chama Section is partly attributed to the proposed decrease in channel capacity downstream of Abiquiu Reservoir from 1,800 to 1,500 cfs. Likewise, the increase in the mean annual maximum acres of overbank flooding in the Central Section is due, in part, to the proposed increase in channel capacity from 7,000 to 8,500 cfs downstream of Cochiti Lake. In the three sections combined, the mean annual maximum acres of overbank flooding would decline by approximately 42 percent (1,330 acres).

In the Rio Chama and San Acacia Sections, the extent and duration of spring overbank flooding over the 40-year modeling period would decrease by 6 percent (67 acre-days) and 64 percent (85,009 ac-ft), respectively. In the Central Section, the extent and duration of overbank flooding would increase by approximately 10 percent (783 ac-ft). For the three sections combined, the mean duration of overbank flooding would decline by approximately 60 percent (84,293 acre-days).

Under Alternative B-3, longnose dace habitat in the Rio Chama, Central, and San Acacia Sections combined would decline by approximately 12.7 percent (105,999 ft^2) on average, with the largest habitat losses (58.5 percent 88,240 ft^2)) occurring in the San Acacia Section. Channel catfish habitat would decline by approximately 8.2 percent (220,763 ft^2), with the largest habitat losses (40.2 percent (199,925 ft^2)) occurring in the San Acacia Section. Flathead chub and river carpsucker habitat would decline by 8.0 percent (91,348 ft^2), with the largest habitat losses (41.1 percent (97,736 ft^2)) again occurring in the San Acacia Section.

Threatened and Endangered Species
Issues with federally listed species will be addressed in detail during section 7 consultation under the Act.

DISCUSSION

The Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661-667e) directs the Federal action agency to consult with the Service for purposes of "preventing a net loss of and damage to wildlife resources." It further directs the action agency to give wildlife conservation measures equal consideration to features of water resource development. Consideration is to be given to all wildlife, not simply those that are legally protected under the Endangered Species Act or those with high economic and recreational value. Further, the recommendations of the Service are to be given full consideration by the action agency. All aspects of the proposed project should be managed to avoid and minimize impacts to wildlife resources.

Water development projects that result in adverse impacts to fish and wildlife require the development of mitigation plans. These plans consider the value of fish and wildlife habitat affected. The Service has established a mitigation policy used as guidance in recommending mitigation (Service 1981). The policy states that the degree of mitigation should correspond to the value and scarcity of the fish and wildlife habitat at risk. Four resource categories in decreasing order of importance are identified:

Resource Category No. 1 Habitats of high value for the species being evaluated that are unique and irreplaceable on a national basis or in the ecoregion section. No loss of existing habitat value should occur.

Resource Category No. 2 Habitats of high value that are relatively scarce or becoming scarce on a national basis or in the ecoregion section. No net loss of in-kind habitat value should occur.

Resource Category No. 3 Habitats of high to medium value that are relatively abundant on a national basis. No net loss of habitat value should occur and loss of in-kind habitat should be minimized.

Resource Category No. 4 Habitats of medium to low value. Loss of habitat value should be minimized.

The habitats in the immediate project area are classified as follows: Resource Category No. 2 - riparian vegetation (includes trees and shrubs such as willows) and aquatic habitat.

Riparian habitats are classified in category 2 because they are scarce and are rapidly disappearing. About 90 percent of the historic wetland and riparian habitat in the Southwest has been eliminated (Johnson and Jones 1977). The mitigation goal for riparian areas (trees and shrubs) in the project area is no net loss in wildlife value as a result of the proposed project. To ensure that mitigation is successful for impacts to riparian habitats, we recommend that a long-term monitoring and mitigation plan be developed.

Aquatic habitats are classified in category 2 because they are relatively scarce in the Southwest and provide high wildlife value for several native fish species (e.g., longnose dace, flathead chub, river carpsucker, etc.). The mitigation goal for aquatic habitat (e.g., backwaters, riffles, and runs) in the project area is to have no net loss of habitat value as a result of the proposed project. To ensure that mitigation is successful for impacts to aquatic habitats, we recommend that a long-term monitoring and mitigation plan be developed.

The Service has ranked the Project alternatives in terms of their potential impacts on aquatic and terrestrial resources from least to most:

- Alternative I-1
- Alternative I-2
- Alternative I-3
- Alternative D-3
- Alternative E-3
- Alternative B-3
- No Action

The proposed project would include actions that could have both positive and negative impacts on fish and wildlife resources in the project area. Actions that could potentially benefit fish and wildlife resources include conservation storage of native Rio Grande flood carry-over water at Abiquiu Reservoir, and increasing the capacity of the river channel downstream of Abiquiu Reservoir and Cochiti Lake. Conservation storage could be used to augment peak flows during low flow years, minimize intermittency, trigger spawning, and meet other life history requirements of fish and wildlife downstream. Increasing the channel capacity downstream of Abiquiu Reservoir and Cochiti Lake could facilitate higher magnitude releases and promote overbank flooding, scouring, deposition, and other natural hydrologic processes that create and maintain diverse aquatic and riparian habitats.

Although conservation storage could benefit fish and wildlife resources, it could also negatively impact these resources as well. Increased storage at Abiquiu Reservoir could further regulate the hydrograph and diminish naturally occurring high flow events that create and maintain fish and wildlife habitats. It could also reduce flows necessary for spawning, rearing, and other fish and wildlife life history requirements. Furthermore, the release of conservation storage in November and December as modeled in URGWOPs, would provide little if any benefit to fish and wildlife resources. The Service strongly recommends that the joint lead agencies seek to obtain the authority and flexibility to manage conservation storage in a manner that maximizes benefits to fish and wildlife resources while also assisting the NMISC in meeting their downstream delivery obligations. This authority should include the ability to carry-over conservation storage from year-to-year and release it in a manner and at times (i.e., spring and summer) most beneficial to fish and wildlife resources.

Of the operational changes proposed, diversions into the LFCC would cause the most impacts to fish and wildife resources. Because of the wide range of potential diversions (e.g., 0 to 2,000 cfs), implementation of each alternative as proposed could have major impacts to fish and wildlife resources in the San Acacia Section that would be difficult to mitigate, if not impossible. This is because under all of the alternatives as proposed, diversions could occur whenever flows at the San Acacia Diversion Dam exceed 250 cfs. For example, under Alternative B-3, up to 89 percent of the river flow could be diverted into the LFCC when flows at San Acacia are 2,250 cfs. Although these diversions may benefit wetlands west of the LFCC, they could reduce available instream habitat by 89 percent or more, significantly impacting fish and wildlife resources. Even under Alternative I-1 where diversions are capped at 500 cfs, up to 67 percent of the river flow could be diverted into the LFCC. If rates of entrainment correspond to the proportion of river flow diverted, then up to 89 percent and 67 percent of the eggs and larve in the drift at San Acacia could be entrained into the LFCC under Alternatives B-3 and I-1, respectively.

Diversion related impacts to fish and wildlife could be reduced to a mitigable level by limiting the magnitude of flow diverted from the river and diverting only what is necessary to improve downstream deliveries. The joint lead agencies should continue to study the surface and groundwater hydrology of the river and LFCC in the San Acacia Section to determine the level of diversions required to improve downstream deliveries. Only those levels shown to improve deliveries should be considered for diversion, and only when they comprise a small proportion of the flow in the river. However, to the extent possible, diversions should be avoided to ensure the protection of fish and wildlife resources in the San Acacia Section.

To further reduce diversion related impacts to fish and wildlife resources, the joint lead agencies should redesign the diversion structure at San Acacia to minimize or avoid entraining fish, eggs, and larvae into the LFCC. To avoid entrainment related impacts, the joint lead agencies should investigate the feasibility of infiltration galleries rather than a surface diversion. If infiltration galleries are found to be infeasible, then the diversion structure should be screened and include design features to reduce approach velocities. Reducing the approach velocities would help to minimize entrainment and impingement of fish, larvae, and other aquatic biota on the intake screens.

To further minimize diversion related impacts to fish and wildlife resources, the joint lead agencies should consider increasing the channel capacity below Abiquiu Reservoir and Cochiti Lake, and avoid decreasing channel capacity and further limiting management flexibility. Channel capacity increases could facilitate higher magnitude releases from Abiquiu Reservoir and Cochiti Lake that could benefit fish and wildlife resources in the Rio Chama and Central Sections while minimizing diversion related impacts in the San Acacia Section. Higher magnitude spring releases from Cochiti Lake could be timed to increase spring peak flows in the Central Section above levels typically considered safe for the San Marcial railroad bridge downstream. This “extra” water could then be diverted from the river into the LFCC ensuring flows at the San Marcial railroad bridge remain at a safe level. Thus, fish and wildife resources in the Central Section could benefit from larger spring peak flows, diversion related flow reductions downstream of the San Acacia Diversion Dam could be minimized or avoided, and flows below the San Marcial railroad bridge could remain within safe levels.

Without diversions into the LFCC the proposed project would result in a net benefit to fish and wildlife resources. Conservation storage could be used to increase peak flows necessary for habitat creation and maintenance as well as provide spawning cues necessary for other life history requirements. It could also be used to reduce intermittency downstream and help to maintain habitat during critical low-flow periods. Increasing the channel capacities below Abiquiu Reservoir and Cochiti Lake could facilitate higher spring releases and channel forming and maintaining flows. Large diversions into the LFCC would be difficult if not impossible to mitigate, particularly with the wide variability of diversions proposed in each alternative.

RECOMMENDATIONS

To avoid or minimize project related impacts to fish and wildlife resources, we recommend that the joint lead agencies:

1. Develop a long-term monitoring and mitigation plan to identify and offset project related impacts to aquatic and riparian habitats.

2. Obtain the authority to carry-over conservation storage from year-to-year and release it in a manner and at times (i.e., spring and summer) most beneficial to fish and wildlife resources.

3. Continue studying the surface and groundwater hydrology of the river and LFCC in the San Acacia Section to determine the level of diversions necessary to improve downstream deliveries.

4. To the extent possible, minimize, diverting into the LFCC. Divert only the amount necessary to improve downstream deliveries, and only when diversions would comprise a small proportion of the flow in the river.

5. Investigate the use of infiltration galleries instead of a surface diversion at San Acacia.

6. Redesign the LFCC intake to include screens and minimize approach velocities.

7. Increase the channel capacity below Abiquiu Reservoir and Cochiti Lake.

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Appendix A. Common and Scientific Names of Fish That May Occur in the URGWOPs Project Area.

Common Name	Scientific Name
Gizzard shad (N)	*Dorosoma cepedianum*
Rainbow trout (I)	*Oncorhynchus mykiss*
Brown trout (I)	*Salmo trutta*
Northern pike (I)	*Esox lucius*
Red shiner (N)	*Cyprinella lutrensis*
Common carp (I)	*Cyprinus carpio*
Rio Grande chub (N)	*Gila pandora*
Rio Grande silvery minnow (N)	*Hybognathus amarus*
Fathead minnow (N)	*Pimephales promelas*
Flathead chub (N)	*Platygobio gracilis*
Longnose dace (N)	*Rhinichthys cataractae*
River carpsucker (N)	*Carpiodes carpio*
Flathead catfish (N)	*Pylodictis olivaris*
White sucker (I)	*Catostomus commersoni*
Rio Grande sucker (N)	*Catostomus plebeius*
Smallmouth buffalo (N)	*Ictiobus bubalus*
Black bullhead (I)	*Ictalurus melas*
Yellow bullhead (I)	*Ictalurus natalis*
Channel catfish (I)	*Ictalurus punctatus*
Western mosquitofish (N)	*Gambusia affinis*
White bass (I)	*Morone chrysops*
Green sunfish (I)	*Lepomis cyanellus*
Bluegill (N)	*Lepomis macrochirus*
Longear sunfish (I)	*Lepomis megalotis*
Largemouth bass (I)	*Micropterus salmoides*
White crappie (I)	*Pomoxis annularis*
Black crappie (I)	*Pomoxis nigromaculatus*
Yellow perch (I)	*Perca flavescens*

(N=native, I=introduced or non-native)

Appendix B. Common and Scientific Names of Plants That May Occur in the URGWOPs Project Area.

Common Name	Scientific Name
Baccharis (N)	*Baccharis spp.*
Seepwillow (N)	*Baccharis glutinosa*
Coyote willow (N)	*Salix exigua*
Peachleaf willow (N)	*Salix amygdaloides*
Goodding's willow (N)	*Salix gooddingii*
Buttonbush (N)	*Cephalanthus spp.*
False indigo bush (N)	*Amorpha fruticosa*
New Mexico olive (N)	*Forestiera neomexicana*
Black locust (N)	*Robinia pseudo-acacia*
Boxelder (N)	*Acer negundo*
Chinaberry (I)	*Melia azedarach*
Rio Grande cottonwood (N)	*Populus fremonti*
White mulberry (I)	*Morus alba*
Russian olive (I)	*Elaeagnus angustifolia*
Salt cedar (I)	*Tamarix spp.*
Siberian elm (I)	*Ulmus pumila*
Tree-of-heaven (I)	*Ailanthus altissima*
Apache plume (N)	*Fallugia paradoxa*
Wolfberry (N)	*Lycium andersonii*
Fourwing saltbush (N)	*Atriplex canescens*
Virginia creeper (I)	*Parthenocissus inserta*
Phragmites (N)	*Phragmites communis*
Sago pondweed (N)	*Potamogeton pectinatus*
Sedge (N)	*Carex spp.*
Saltgrass (N)	*Distichlis stricta*
Spikerush(N)	*Eleocharis spp.*
Horsetail (N)	*Equisetum spp.*
Rush (N)	*Juncus spp.*
Bulrush (N)	*Scirpus spp.*
Sacaton (N)	*Sporobolus spp.*
Cattail (N)	*Typha latifolia*
Smartweed (N)	*Polygonum lapathifolium*
American milfoil (N)	*Myriophyllum exalbescens*
Yerba manza (N)	*Anemopsis californica*
Primrose (N)	*Oenothera spp.*
Fendler globemallow (N)	*Sphaeralcea fendleri*
Pricklypear (N)	*Opuntia spp.*
Buffalo gourd (N)	*Cucurbita foetidissima*
Spiny aster (I)	*Aster spinosus*
Golden currant (N)	*Ribes aureum*
Watercress (N)	*Nasturtium officionale*

(N=native, I=introduced or non-native)

Appendix C. Common and Scientific Names of Mammals That May Occur in the URGWOPs Project Area.

Common Name	Scientific Name
Opossum	*Didelphis virginiana*
Desert shrew	*Notiosorex crawfordi*
Yuma myotis	*Myotis yumanensis*
Little brown bat	*Myotis lucifugus*
Long-legged myotis	*Myotis volans*
Silver-haired bat	*Lasionycteris noctivagans*
Big brown bat	*Eptesicus fuscus*
Hoary bat	*Lasiurus cinereus*
Spotted bat	*Euderma maculatum*
Townsend’s big-eared bat	*Plecotis townsendii*
Pallid bat	*Antrozous pallidus*
Brazilian free-tailed bat	*Tadarida brasiliensis*
Desert cottontail	*Sylvilagus auduboni*
Black-tailed jackrabbit	*Lepus californicus*
Beaver	*Castor canadensis*
Gunnison’s prairie dog	*Cynomys gunnisoni*
Colorado chipmunk	*Eutamias quadrivittatus*
Spotted ground squirrel	*Spermophilus spilosoma*
Rock squirrel	*Spermophilus variegatus*
Red squirrel	*Tamiasciurus hudsonicus*
Northern grasshopper mouse	*Onychomys leucogaster*
Deer mouse	*Peromyscus maniculatus*
White-footed mouse	*Peromyscus leucopus*
Piñon mouse	*Peromyscus truei*
Western harvest mouse	*Reithrodontomys megalotis*
Hispid cotton rat	*Sigmodon hispidus*
Norway rat	*Rattus norvegicus*
Muskrat	*Ondatra zibethicus*
New Mexican jumping mouse	*Zapus hudsonius luteus*
Ord kangaroo rat	*Dipodomys ordii*
Merriam kangaroo rat	*Dipodomys merriami*
Silky pocket mouse	*Perognathus flavus*
Plains pocket mouse	*Perognathus flavescens*
Yellow-faced pocket gopher	*Pappogeomys castanops*
Botta pocket gopher	*Thomomys bottae*
American porcupine	*Erethizon dorsatum*
Coyote	*Canis latrans*
Gray fox	*Urocyon cinereoargenteus scottii*
Raccoon	*Procyon lotor*
Striped skunk	*Mephitis mephitis*
Long-tailed weasel	*Mustela frenata*
Mink	*Mustela vison*
Badger	*Taxidea taxus*
Bobcat	*Lynx rufus*
Mountain lion	*Felis concolor*
Mule deer	*Odocoileus hemionus*

Appendix D. Common and Scientific Names of Birds That May Occur in the URGWOPs Project Area.

Common Name	Scientific Name
Pied-billed grebe	*Podilymbus podiceps*
Common loon	*Gavia immer*
American white pelican	*Pelecanus erythrorhynchos*
Double-crested cormorant	*Phalacrocorax auritus*
Olivaceous cormorant	*Phalacrocorax olivaceus*
American bittern	*Botaurus lentiginosus*
Least Bittern	*Ixobrychus exilis*
Great blue heron	*Ardea herodias*
Great egret	*Ardea alba*
Snowy egret	*Egretta thula*
Little blue heron	*Egretta caerulea*
Cattle egret	*Bubulcus ibis*
Green-backed heron	*Butorides striatus*
Black-crowned night heron	*Nycticorax nycticorax*
White-faced ibis	*Plegadis chihi*
Snow goose	*Chen caerulescens*
Canada goose	*Branta canadensis*
Wood duck	*Aix sponsa*
Green-winged teal	*Anas crecca*
Mallard	*Anas platyrhynchos*
Northern pintail	*Anas acuta*
Cinnamon teal	*Anas cyanoptera*
Northern shoveler	*Anas clypeata*
Gadwall	*Anas strepera*
Hooded merganser	*Mergus cuculatus*
Red-breasted merganser	*Mergus serrator*
Ruddy duck	*Oxyura jamaicensis*
Virginia rail	*Rallus limicola*
Sora	*Porzana carolina*
Common moorhen	*Gallinula chloropus*
American coot	*Fulica americana*
Sandhill crane	*Grus canadensis*
Whooping crane	*Grus americana*
Killdeer	*Charadrius vociferus*
Black-necked stilt	*Himantopus mexicanus*
American avocet	*Recurvirostra americana*
Solitary sandpiper	*Tringa solitaria*
Spotted sandpiper	*Actitis macularia*
Long-billed curlew	*Numenius americanus*
Forster's tern	*Sterna forsteri*
Black tern	*Chlidonias niger*
Turkey vulture	*Cathartes aura*
Osprey	*Pandion haliaetus*
Black-shouldered kite	*Elanus caeruleus*
Mississippi kite	*Ictinia mississippiensis*

Appendix D continued. Common and Scientific Names of Birds That May Occur in the URGWOPs Project Area.

Common Name	**Scientific Name**
Bald eagle	*Haliaeetus leucocephalus*
Northern Harrier	*Circus cyaneus*
Cooper's hawk	*Accipiter cooperii*
Common black-hawk	*Buteogallus anthracinus*
Swainson’s hawk	*Buteo swainsoni*
Red-tailed hawk	*Buteo jamaicensis*
American kestrel	*Falco sparverius*
American peregrine falcon	*Falco peregrinus anatum*
Ring-necked pheasant	*Phasianus colchicus*
Northern bobwhite	*Colinus virginianus*
Scaled quail	*Callipepla squamata*
Gambel’s quail	*Callipepla gambelii*
Rock dove	*Columba livia*
White-winged dove	*Zenaida asiatica*
Morning dove	*Zenaida macroura*
Common ground-dove	*Columbina passerina*
Yellow-billed cuckoo	*Coccyzus erythropthalmus*
Greater roadrunner	*Geococcyx californianus*
Common barn-owl	*Tyto alba*
Great horned owl	*Bubo virginianus*
Burrowing owl	*Athene cunicularia*
Lesser nighthawk	*Chordeiles acutipennis*
Common nighthawk	*Chordeiles minor*
White-throated swift	*Aeronautes saxatalis*
Black-chinned hummingbird	*Archilochus alexandri*
Rufous hummingbird	*Selasphorus rufus*
Belted kingfisher	*Ceryle alcyon*
Northern flicker	*Colaptes auratus*
Olive-sided flycatcher	*Contopus borealis*
Western wood-pewee	*Contopus sordidulus*
Southwestern willow flycatcher	*Empidonax traillii extimus*
Black phoebe	*Sayornis nigricans*
Say’s phoebe	*Sayornis saya*
Ash-throated flycatcher	*Myiarchus cinerascens*
Cassin’s kingbird	*Tyrannus vociferans*
Western kingbird	*Tyrannus verticalis*
Eastern kingbird	*Tyrannus tyrannus*
Violet-green swallow	*Tachycineta thalassina*
Bank swallow	*Riparian riparia*
Cliff swallow	*Hirundo pyrrhonota*
Barn swallow	*Hirundo rustica*
Northern rough-winged swallow	*Stelgidopteryx serripennis*
Black-billed magpie	*Pica pica*
American crow	*Corvus caurinus*
Chihuahuan raven	*Corvus cryptoleucus*

Appendix D continued. Common and Scientific Names of Birds That May Occur in the URGWOPs Project Area.

Common Name	Scientific Name
Black-capped chickadee	*Parus atricapillus*
Verdin	*Auriparus flaviceps*
White-breasted nuthatch	*Sitta carolinensis*
Cactus wren	*Campylorhynchus brunneicapillus*
Black-tailed gnatcatcher	*Polioptila melanura*
Eastern bluebird	*Sialia sialis*
Western bluebird	*Sialia mexicana*
Hermit thrush	*Catharus guttatus*
American robin	*Turdus migratorius*
Gray catbird	*Dumetella carolinensis*
Northern mockingbird	*Mimus polyglottos*
Curved-billed thrasher	*Toxostoma curvirostre*
Crissal thrasher	*Toxostoma dorsale*
European starling	*Sturnus vulgaris*
Bell’s vireo	*Vireo bellii*
Warbling vireo	*Vireo gilvus*
Orange-crowned warbler	*Vermivora celata*
Virginia’s warbler	*Vermivora virginiae*
Lucy’s warbler	*Vermivora luciae*
Yellow warbler	*Dendroica petechia*
Yellow-rumped warbler	*Dendroica coronata*
Common yellowthroat	*Geothlypis trichas*
Wilson’s warbler	*Wilsonia pusilla*
Yellow-breasted chat	*Icteria virens*
Summer tanager	*Piranga rubra*
Western tanager	*Piranga ludoviciana*
Northern cardinal	*Cardinalis cardinalis*
Pyrrhuloxia	*Cardinalis sinuatus*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Black-headed grosbeak	*Pheucticus melanocephalus*
Blue grosbeak	*Guiraca caerulea*
Lazuli bunting	*Passerina amoena*
Indigo bunting	*Passerina cyanea*
Painted bunting	*Passerina ciris*
Spotted towhee	*Pipilo maculatus*
Brown towhee	*Pipilo fuscus*
Dark-eyed junco	*Junco hyemalis*
Rufous-crowned sparrow	*Aimophila ruficeps*
American tree sparrow	*Spizella arborea*
Chipping sparrow	*Spizella passerina*
Lark sparrow	*Chondestes grammacus*
Black-throated sparrow	*Amphispiza bilineata*
Lark bunting	*Calamospiza melanocorys*
Lincoln’s sparrow	*Melospiza lincolnii*
White-crowned sparrow	*Zonotrichia leucophrys*

Appendix D continued. Common and Scientific Names of Birds That May Occur in the URGWOPs Project Area.

Common Name	Scientific Name
Red-wing blackbird	*Agelaius phoeniceus*
Western meadowlark	*Sturnella neglecta*
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Brewer's blackbird	*Euphagus cyanocephalus*
Great-tailed grackle	*Quiscalus mexicanus*
Bronzed cowbird	*Molothrus aeneus*
Brown-headed cowbird	*Molothrus ater*
Orchard oriole	*Icterus spurius*
Northern oriole	*Icterus galbula bullockii*
House finch	*Carpodacus mexicanus*

Appendix E. Common and Scientific Names of Reptiles and Amphibians That May Occur in the URGWOPs Project Area.

Common Name	Scientific Name
Western hooknose snake	*Gyalopion canum*
Western hognose snake	*Heterodon nasicus*
Night snake	*Hypsiglena torquata*
Common kingsnake	*Lampropeltis getula*
Milk snake	*Lampropeltis triangulum*
Coachwhip	*Masticophis flagellum*
Striped whipsnake	*Masticophis taeniatus*
Bullsnake or gopher snake	*Pituophis melanoleucus*
Longnose snake	*Rhinocheilus lecontei*
Big Bend patchnose snake	*Salvadora deserticola*
Mountain patchnose snake	*Salvadora grahamiae*
Ground snake	*Sonora semiannulata*
Plains blackhead snake	*Tantilla nigriceps*
Blackneck garter snake	*Thamnophis cyrtopsis*
Wandering garter snake	*Thamnophis elegans*
Checkered garter snake	*Thamnophis marcianus*
Common garter snake	*Thamnophis sirtalis*
Lyre snake	*Trimorphodon biscutatus*
Western diamondback rattlesnake	*Crotalus atrox*
Blacktail rattlesnake	*Crotalus molossus*
Western rattlesnake	*Crotalus viridis*
Massasauga	*Sistrurus catenatus*

APPENDIX M
WATER QUALITY

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1.0 General Description of the Upper Rio Grande Basin

The Rio Grande is an important water resource for residents of and the environment in Colorado, New Mexico, Texas, and the Republic of Mexico. Rio Grande water is repeatedly diverted for irrigation and returned to the river channel directly or through drains, impounded by reservoirs, and lost to evaporation, transpiration, and consumption. Irrigation is the biggest use of Rio Grande water in both the United States and Mexico, accounting for 89 percent of all water taken from the river. Municipal use accounts for 8 percent, and other uses account for 3 percent (RM-1 Levings et al. 1998). As a result of these uses, as well as natural conditions and processes, water quality is altered and streamflow decreases in the downstream direction throughout most of the Basin (RM-2 Healy 1997). The Rio Grande becomes a losing stream downstream of the Otowi Gage, with inflows only from ephemeral or intermittent streams and arroyos that flow during snowmelt and storm runoff, from groundwater, and from return flow from ditches and canals.

Reservoirs are the primary tool for managing water resources in the western and southwestern United States, and both large and small reservoirs contribute to altering the natural flow of water within the Rio Grande Basin. Eighteen reservoirs in the Rio Grande watershed have storage capacities greater than 5,000 acre-feet (RM-3 Moore and Anderholm 2002), holding water for irrigation and/or public use.

The natural variability of surface water quality within the upper Rio Grande Basin can be attributed to a variety of watershed characteristics and hydrologic processes. These processes include the dynamic balance between the chemical composition of surface water, including tributary inflow and groundwater interaction (hyporheic zone), precipitation, surrounding geology, nutrient uptake, erosive capability of the channel and surrounding land, and evapo-transpiration. Anthropogenic activities such as forestry, agriculture, industrial and municipal activities, urban development, road construction, and storm water runoff contribute sediment, nutrients, and other pollutants to the system. These land uses may contribute to deterioration in the surface water quality of the Rio Grande (RM-1 Levings et al. 1998). Specifically, urban areas add volatile compounds, organic chemicals, and pesticides via wastewater effluent and runoff; agricultural areas contribute chemicals from the application of fertilizers and pesticides in return flows and overland flow; mining adds trace elements via mine tailings and can alter the quantity of transported sediment; atmospheric deposition contributes nitrates (HNO_3) and phosphates (H_3O_4P) and additional pollutants carried in from outlying distances; and the use and reuse of water increase dissolved solid concentrations as a result of evapo-transpiration.

Water quality is further impacted by the emplacement of dams and the presence and operation of reservoirs. How these facilities are managed can significantly impact river systems in the arid to semi-arid environments of the Southwest, where water is a seasonal and often scarce resource. Reservoir operations affect water quality by altering water chemistry, natural flow variation, and the transport of sediments, nutrients, and contaminants. Within the Rio Grande watershed, these impacts occur in three primary ways. (1) Reservoirs regulate the downstream flow of sediments, nutrients, and contaminants contributed by groundwater, tributaries, and overland flow sources. Diminished water velocity in reservoirs causes nutrients and suspended sediments to settle, thus decreasing the natural nutrients and sediments in the system. (2) Reservoirs and dams create a unique physical and chemical environment that affects nutrient cycling within the reservoirs, and ultimately may impact riverine environments upstream and downstream of the reservoir. For example, contaminants and nutrients may be sequestered within the sediment of the reservoir, thus decreasing concentrations in downstream reaches; and pollutants may be transformed into alternative forms (e.g., mercury [Hg] to methylmercury (+1) ion [CH^3HG^++], sulfate [$O^4S^{-2}{}_{-2}$] to sulfide [$S^{-2}{}_{-2}$]), discharged unchanged; or accumulated either directly or through food-chain transfers by plants, fish and other aquatic organisms, and wildlife. (3) Reservoirs commonly alter the natural temperature regime downstream. Water released from the depths of a reservoir may produce cooler surface temperatures downstream, altering natural conditions that species have become adapted to. Conversely, water released from higher levels in a reservoir may increase surface temperature downstream; the high heat capacity of the stored reservoir water thus alters the natural cycle and modifies water quality constituents that are influenced by or dependent on water temperature.

The effects of reservoirs on water quality dissipate as flows continue downstream. With distance from the reservoir, the impacts of tributaries, overland flow, atmospheric conditions, adjacent land use, and surrounding geology on local water quality become greater. For example, as water travels downstream after being released from a reservoir, temperature and dissolved oxygen, as well as other constituents, quickly equilibrate with ambient atmospheric conditions. The specific manner in which these changes occur depends on air temperature, storm or snowmelt runoff, land use, and factors such as turbulence within a river reach.

1.1 Regulatory Environment

The Clean Water Act (as amended) and various state regulations such as the New Mexico Water Quality Act of 1978 require the development of water quality standards to protect public and private interests, wildlife, and the quality of waters. In addition, Native American Pueblos within the Rio Grande Basin maintain their own water quality standards and regulations. The project area includes three states (Colorado, New Mexico, and Texas), 11 Native American tribes or pueblos (Taos, San Juan, Santa Clara, San Ildefonso, Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, Isleta, and Jicarilla Apache), and various federal and local agencies with distinct jurisdictional boundaries and concerns directly related to water quality. Water quality within the upper Rio Grande Basin is regulated by the standards of each of the three states, of the Rio Grande Compact of 1938, and of four of the Pueblos (San Juan, Santa Clara, Sandia, and Isleta). At the time of this report, the other Pueblos have either not developed specific water quality standards or the U.S. Environmental Protection Agency (EPA) had not yet adopted their standards.

Each regulatory entity has developed numeric standards, narrative (general) standards, and antidegradation statements to ensure the quality of water. Numeric standards are for water constituents that can be quantified and for which accurate background conditions have been established to provide a threshold for assessing water quality. Narrative standards are used when constituent levels cannot be measured or when background conditions are unknown. Narrative standards are not quantifiable; they provide general guidance to ensure that factors affecting water quality do not exceed baseline conditions. Antidegradation statements declare that existing uses of water must be maintained and protected. Through these statements, states must protect current uses and prevent waters from deteriorating. States and Tribes also use antidegradation statements to protect against hydrologic and physical alterations. They can be applied to all waters, with or without numeric or narrative standards, to ensure that waters are not degraded beyond their current condition without specific authorization. When water bodies are not in compliance with any of these standards, they are subject to enforcement actions under Clean Water Act sections 303(d) and 305(b).

1.2 Reach Descriptions

For the Upper Rio Grande Water Operations (URGWOPS) Environmental Impact Statement (EIS), 17 unique river reaches were defined based on changes in channel geomorphology and hydrology. The Water Quality Resource Team (WQRT) of the URGWOPS Review and EIS evaluated the applicable federal, state, tribal, and compact standards and jurisdictional boundaries within the 17 reaches and defined 42 unique water quality assessment subreaches (WQRs) to address conditions specific to those portions of the Rio Grande (**Table M-1.1**). The boundaries of these reaches were set either where a change in water quality regulations or land governance occurred or where waters entered or left a reservoir. The following section describes the boundaries of each reach and defines the standards that apply to that reach.

Table M-1.1. Water Quality Subreach Numbers and Boundaries as Defined by the Water Quality Resource Team of the Upper Rio Grande Water Operations Review and EIS

WQR	REACH NAME	WATER QUALITY JURISDICTIONAL AUTHORITY
1.1	Rio Grande upstream of Closed Basin Project	State of Colorado
1.2	Closed Basin project discharge	State of Colorado/Rio Grande Compact
1.3	Rio Grande Closed Basin discharge to Conejos River	State of Colorado
1.4	Rio Grande Conejos confluence to New Mexico state line	State of Colorado
2.1	Conejos River inflow to Platoro Reservoir	State of Colorado
2.2	Platoro Reservoir	State of Colorado
2.3	Conejos River below Platoro Reservoir	State of Colorado
3.1	Rio Grande Colorado state line to Taos Pueblo	State of New Mexico
3.2	Rio Grande Taos Pueblo	State of New Mexico / Taos Pueblo
3.3	Rio Grande Taos Pueblo to Velarde	State of New Mexico
4.1	Rio Grande Velarde to San Juan Pueblo	State of New Mexico
4.2	Rio Grande on San Juan Pueblo to the Rio Chama	San Juan Pueblo
5.1	Rio Chama above Heron Reservoir outflow	State of New Mexico
5.2	Heron Reservoir	State of New Mexico
5.3	Rio Chama Heron Reservoir to El Vado Reservoir	State of New Mexico
6.1	El Vado Reservoir	State of New Mexico
6.2	Rio Chama El Vado Reservoir to Abiquiu Reservoir	State of New Mexico
7.1	Abiquiu Reservoir	State of New Mexico
7.2	Rio Chama Abiquiu Reservoir to San Juan Pueblo	State of New Mexico
7.3	Rio Chama on San Juan Pueblo	San Juan Pueblo
8.0.a	Rio Grande below Rio Chama confluence on San Juan Pueblo	San Juan Pueblo
8.0.b	Rio Grande San Juan Pueblo to Santa Clara Pueblo	State of New Mexico
8.0.c	Rio Grande on Santa Clara Pueblo	Santa Clara Pueblo
8.0.d	Rio Grande Santa Clara Pueblo to Otowi	San Ildefonso Pueblo / State of New Mexico
9.0	Rio Grande Otowi Gage to Cochiti Reservoir	San Ildefonso, Cochiti Pueblos / State of New Mexico
10.1	Cochiti Reservoir	Cochiti Pueblo / State of New Mexico
10.2	Rio Grande–Cochiti Reservoir to Jemez River	Cochiti, Santo Domingo, San Felipe Pueblos
10.3	Rio Grande–Jemez confluence to Bernalillo (Hwy 550)	San Felipe Pueblo / State of New Mexico
11.1	Jemez River inflow	Santa Ana Pueblo / State of New Mexico
11.2	Jemez Reservoir	Santa Ana Pueblo / State of New Mexico
11.3	Jemez River below Jemez Reservoir to Rio Grande	Santa Ana Pueblo / State of New Mexico
12.0.a	Rio Grande on Sandia Pueblo	Sandia Pueblo
12.0.b	Rio Grande Sandia Pueblo to Isleta Pueblo	State of New Mexico
12.0.c	Rio Grande on Isleta Pueblo	Isleta Pueblo
13.0	Rio Grande Isleta Diversion Dam to Rio Puerco	State of New Mexico
14.0	Rio Grande Rio Puerco to Elephant Butte Reservoir	State of New Mexico
15.1	Elephant Butte Reservoir	State of New Mexico
15.2	Rio Grande Elephant Butte to Caballo Reservoir	State of New Mexico
16.1	Caballo Reservoir	State of New Mexico
16.2	Caballo Reservoir to TX State Line	State of New Mexico
17.1	Rio Grande TX State Line to America Diversion Dam	State of Texas/ Republic of Mexico
17.2	Rio Grande American Diversion to Ft. Quitman TX	State of Texas/ Republic of Mexico

1.2.1 Applicable Standards for Water Quality Reaches (WQR)

WQR 1.1

Mainstem of the Rio Grande from a point immediately above the confluence with Willow Creek to the Rio Grande/Alamosa County line

Colorado Standards:

A. Designated Uses: coldwater aquatic life 1, recreation 1, water supply, agriculture

B. Standards:

- **(1)** Physical and Biological: Temperature, 20^{o} C, DO = 6.0 mg/L (7.0 mg/L during fish spawning), pH = 6.5-9.0, fecal coliform = 200/100 mL
- **(2)** Metals: Arsenic (As) (acute, total recoverable) = 50 ug/L, Mercury (Hg) (chronic, total recoverable) = 0.01 ug/L
- **(3)** Narrative Standards: Except where authorized by permits, Best Management Practices (BMPs), 401 certifications, or plans of operation approved by the Division or other applicable agencies, state surface waters shall be free from substances attributable to human-caused point source or non-point source discharge in amounts, concentrations or combinations which:
  - (a) for all surface waters except wetlands;
    - (i) can settle to form bottom deposits detrimental to the beneficial uses. Depositions are stream bottom buildup of materials which include but are not limited to anaerobic sludges, mine slurry or tailings, silt, or mud; or
    - (ii) form floating debris, scum, or other surface materials sufficient to harm existing beneficial uses; or
    - (iii) produce color, odor, or other conditions in such a degree as to create a nuisance or harm existing beneficial uses or impart any undesirable taste to significant edible aquatic species or to the water; or
    - (iv) are harmful to the beneficial uses or toxic to humans, animals, plants, or aquatic life; or
    - (v) produce a predominance of undesirable aquatic life; or
    - (vi) cause a film on the surface or produce a deposit on shorelines;

WQR 1.2

1.2.1.1 Closebed basin project discharge

Rio Grande Compact Standards:

A. Standards:

- **(1)** The Rio Grande Compact, which provides for apportionment of the flows of the Rio Grande among the concerned states, recognized the potentialities for delivery of Closed Basin waters to the Rio Grande and provides that Colorado shall be credited with the amount of such water delivered to the compact station at Lobatos, CO if the proportion of sodium ions in the salvaged water shall be less than 45 percent of the total positive ions when the total dissolved solids in such water exceeds 350 parts per million.

WQR 1.3, 1.4

Mainstem of the Rio Grande from the Rio Grande/Alamosa County line to the Old State Bridge east of Lobatos (Conejos County Road G)

Colorado Standards:

A. Designated Uses: warmwater aquatic life 1, recreation 1, agriculture
B. Standards:
- **(1)** Physical and Biological: Temperature, 20^o C, DO = 6.0 mg/L, pH = 6.5-9.0, fecal coliform = 200/100 mL
- **(2)** Metals: As (acute, total recoverable) = 100 ug/L, Hg (chronic, total recoverable) = 0.01 ug/L
- **(3)** Narrative Standards: Except where authorized by permits, BMPs, 401 certifications, or plans of operation approved by the Division or other applicable agencies, state surface waters shall be free from substances attributable to human-caused point source or non-point source discharge in amounts, concentrations or combinations which:
  - (a) for all surface waters except wetlands;
    - (i) can settle to form bottom deposits detrimental to the beneficial uses. Depositions are stream bottom buildup of materials which include but are not limited to anaerobic sludges, mine slurry or tailings, silt, or mud; or
    - (ii) form floating debris, scum, or other surface materials sufficient to harm existing beneficial uses; or
    - (iii) produce color, odor, or other conditions in such a degree as to create a nuisance or harm existing beneficial uses or impart any undesirable taste to significant edible aquatic species or to the water; or
    - (iv) are harmful to the beneficial uses or toxic to humans, animals, plants, or aquatic life; or
    - (v) produce a predominance of undesirable aquatic life; or
    - (vi) cause a film on the surface or produce a deposit on shorelines;

WQR 1.4

Mainstem of the Rio Grande from the Old State Bridge east of Lobatos (Conejos County Road G) to the Colorado/New Mexico border

Colorado Standards:

A. Designated Uses: coldwater aquatic life 1, recreation 1, agriculture
B. Standards:
- **(1)** Physical and Biological: Temperature, 20^o C, DO = 6.0 mg/L (7.0 mg/L during fish spawning), pH = 6.5-9.0, fecal coliform = 200/100 mL
- **(2)** Metals: As (acute, total recoverable) = 100 ug/L, Hg (chronic, total recoverable) = 0.01 ug/L
- **(3)** Narrative Standards: Except where authorized by permits, BMPs, 401 certifications, or plans of operation approved by the Division or other applicable agencies, state surface waters shall be free from substances attributable to human-caused point source or non-point source discharge in amounts, concentrations or combinations which:
  - (a) for all surface waters except wetlands;

(i) can settle to form bottom deposits detrimental to the beneficial uses. Depositions are stream bottom buildup of materials which include but are not limited to anaerobic sludges, mine slurry or tailings, silt, or mud; or
(ii) form floating debris, scum, or other surface materials sufficient to harm existing beneficial uses; or
(iii) produce color, odor, or other conditions in such a degree as to create a nuisance or harm existing beneficial uses or impart any undesirable taste to significant edible aquatic species or to the water; or
(iv) are harmful to the beneficial uses or toxic to humans, animals, plants, or aquatic life; or
(v) produce a predominance of undesirable aquatic life; or
(vi) cause a film on the surface or produce a deposit on shorelines;

WQR 2.1, 2.2, 2.3

Mainstem of the Conejos River including all tributaries, wetlands, lakes, and reservoirs from source to immediately above the confluence with Fox Creek; and, Mainstem of the Conejos River from a point immediately above the confluence with Fox Creek to the confluence with the San Antonio River, CO.

Colorado Standards:

A. Designated Uses: coldwater aquatic life 1 and 2, recreation 1, water supply, agriculture
B. Standards:
(1) Physical and Biological: Temperature, 20^{o} C, DO = 6.0 mg/L (7.0 mg/L during fish spawning), pH = 6.5-9.0, fecal coliform = 200/100 mL
(2) Metals: As (acute, total recoverable) = 50 ug/L, Hg (chronic, total recoverable) = 0.01 ug/L
(3) Narrative Standards: Except where authorized by permits, BMPs, 401 certifications, or plans of operation approved by the Division or other applicable agencies, state surface waters shall be free from substances attributable to human-caused point source or non-point source discharge in amounts, concentrations or combinations which:
(a) for all surface waters except wetlands;
(i) can settle to form bottom deposits detrimental to the beneficial uses. Depositions are stream bottom buildup of materials which include but are not limited to anaerobic sludges, mine slurry or tailings, silt, or mud; or
(ii) form floating debris, scum, or other surface materials sufficient to harm existing beneficial uses; or
(iii) produce color, odor, or other conditions in such a degree as to create a nuisance or harm existing beneficial uses or impart any undesirable taste to significant edible aquatic species or to the water; or
(iv) are harmful to the beneficial uses or toxic to humans, animals, plants, or aquatic life; or
(v) produce a predominance of undesirable aquatic life; or
(vi) cause a film on the surface or produce a deposit on shorelines;

WQR 2.3

Mainstem of the Conejos River from the confluence with the San Antonio River to the confluence with the Rio Grande

Colorado Standards:

A. Designated Uses: warmwater aquatic life 2, recreation 2, agriculture

B. Standards:

(1) Physical and Biological: Temperature, 25° C, DO = 5.0 mg/L, pH = 6.5-9.0, fecal coliform = 200/100 mL

(2) Metals: As (acute, total recoverable) = 100 ug/L, Hg (chronic, total recoverable) = Table Value Standard

(4) Narrative Standards: Except where authorized by permits, BMPs, 401 certifications, or plans of operation approved by the Division or other applicable agencies, state surface waters shall be free from substances attributable to human-caused point source or non-point source discharge in amounts, concentrations or combinations which:

(a) for all surface waters except wetlands;

(i) can settle to form bottom deposits detrimental to the beneficial uses. Depositions are stream bottom buildup of materials which include but are not limited to anaerobic sludges, mine slurry or tailings, silt, or mud; or

(ii) form floating debris, scum, or other surface materials sufficient to harm existing beneficial uses; or

(iii) produce color, odor, or other conditions in such a degree as to create a nuisance or harm existing beneficial uses or impart any undesirable taste to significant edible aquatic species or to the water; or

(iv) are harmful to the beneficial uses or toxic to humans, animals, plants, or aquatic life; or

(v) produce a predominance of undesirable aquatic life; or

(vi) cause a film on the surface or produce a deposit on shorelines;

WQR 3.1, 3.2

Rio Grande Basin – The main stem of the Rio Grande from Taos Junction bridge upstream to the New Mexico-Colorado line

New Mexico Standards (20.6.4.122):

A. Designated Uses: coldwater fishery, fish culture, irrigation, livestock watering, wildlife habitat, and primary contact

B. Standards:

(1) In any single sample: pH shall be within the range of 6.6 to 8.8, temperature shall not exceed 20°C (68°F), and turbidity shall not exceed 50 Nephelometric Turbidity Units (NTU). The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations, which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state.

WQR 3.3, 4.1, 4.2, 8.0b, 8.0d, 9.0

Rio Grande Basin – The main stem of the Rio Grande from the headwaters of Cochiti reservoir upstream to Taos Junction bridge

New Mexico Standards (20.6.4.114):

A. Designated Uses: irrigation, livestock watering, wildlife habitat, marginal coldwater fishery, primary contact, and warmwater fishery.

B. Standards:

(1) In any single sample: pH shall be within the range of 6.6 to 9.0, temperature shall not exceed 22°C (71.6°F), and turbidity shall not exceed 50 NTU. The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 200/100 mL; no single sample shall exceed 400/100 mL. (see Subsection B of 20.6.4.13 NMAC).

(3) At mean monthly flows above 100 cfs, the monthly average concentration for: TDS shall not exceed 500 mg/L, sulfate shall not exceed 150 mg/L, and chloride (Cl^-) shall not exceed 25 mg/L.

(4) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations, which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state.

WQR 5.1, 5.3

Rio Grande Basin – All perennial reaches of tributaries to the Rio Chama above Abiquiu Dam except the Rio Gallina and the Rio Puerco de Chama north of State highway 96 and the main stem of the Rio Chama from the headwaters of El Vado reservoir upstream to the New Mexico-Colorado line.

New Mexico Standards (20.6.4.119):

A. Designated Uses: domestic water supply, fish culture, high quality coldwater fishery, irrigation, livestock watering, wildlife habitat, and secondary contact.

B. Standards:

(1) In any single sample; conductivity shall not exceed 500 umhos (1,000 umhos for Coyote creek), pH shall be within the range of 6.6 to 8.8, temperature shall not exceed 20°C (68°F), and turbidity shall not exceed 25 NTU. The use-specific numeric standards set forth in 20.6.4.13 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 100/100 mL; no single sample shall exceed 200/100 mL (see Subsection B of 20.6.4.13 NMAC).

(3) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations, which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state.

WQR 5.2, 6.1

Rio Grande Basin – El Vado and Heron Reservoirs.

New Mexico Standards (20.6.4.120):

A. Designated Uses: irrigation storage, livestock watering, wildlife habitat, primary contact, and coldwater fishery.

B. Standards:

(1) At any sampling site: pH shall be within the range of 6.6 to 8.8, temperature shall not exceed 20°C (68°F), and turbidity shall not exceed 25 NTU. The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 100/100 mL; no single sample shall exceed 200/100 mL (see Subsection B of 20.6.4.13 NMAC).

(3) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state.

iii. When changes in dissolved oxygen, temperature, dissolved solids, sediment or turbidity in a water of the State is attributable to natural causes or the reasonable operation of irrigation and flood control facilities that are not subject to federal or state water pollution control permitting, numerical standards for temperature, dissolved solids content, dissolved oxygen, sediment or turbidity adopted under the Water Quality Act do not apply. The foregoing provision does not include major reconstruction of storage dams or diversion dams except for emergency actions necessary to protect health and safety of the public, or discharges from municipal separate storm sewers.

WQR 6.2

Rio Grande Basin – The Rio Chama from the headwaters of Abiquiu Reservoir upstream to El Vado Reservoir and the Rio Gallina and Rio Puerco de Chama north of State highway 96.

New Mexico Standards (20.6.4.118)

A. Designated Uses: irrigation, livestock watering, wildlife habitat, primary contact, coldwater fishery, and warmwater fishery

C. Standards:

(1) In any single sample: pH shall be within the range of 6.6 to 8.8, and temperature shall not exceed 26°C (78.8°F). The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 200/100mL; no single sample shall exceed 400/100mL (see Subsection B of 20.6.4.13 NMAC)

(3) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state.

iii. Turbidity – Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

WQR 7.1

Rio Grande Basin – Abiquiu Reservoir

New Mexico Standards (20.6.4.117):

A. Designated Uses: irrigation storage, livestock watering, wildlife habitat, primary contact, coldwater fishery, and warm water fishery.

B. Standards:

(1) At any sampling site: pH shall be within the range of 6.6 to 8.8, and temperature shall not exceed 25°C (77°F). The use specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 100/100 mL; no single sample shall exceed 200/100 mL (see Subsection B of 20.6.4.13 NMAC)

(3) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state.

iii. Turbidity – Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

iv. When changes in dissolved oxygen, temperature, dissolved solids, sediment or turbidity in a water of the state is attributable to natural causes or the reasonable operation of irrigation and flood control facilities that are not subject to federal or state water pollution control permitting, numerical standards for temperature, dissolved solids content, dissolved oxygen, sediment or turbidity adopted under the Water Quality Act do not apply. The foregoing provision does not include major reconstruction of storage dams or diversion dams except for emergency actions necessary to protect health and safety of the public, or discharges from municipal separate storm sewers.

WQR 7.2

The Rio Chama from its mouth on the Rio Grande upstream to Abiquiu Reservoir, the Rio Tusas, the Rio Ojo Caliente, Abiquiu creek, and El Rito creek below the town of El Rito.

New Mexico Standards (20.6.4.116):

A. Designated Uses: irrigation, livestock watering, wildlife habitat, coldwater fishery, warmwater fishery, and secondary contact.

B. Standards:

(1) In any single sample: pH shall be within the range of 6.6 to 8.8, and temperature shall not exceed 31°C (87.8°F). The use specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 1,000/100 mL; no single sample shall exceed 2,000/100 mL (see Subsection B of 20.6.4.13 NMAC)

(3) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state.

iii. Turbidity – Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

WQR 7.3

Segment of the Rio Chama that passes through San Juan Pueblo

San Juan Pueblo Standards:

A. Designated Uses: coldwater fishery, warmwater fishery, primary contact ceremonial, primary contact recreational, secondary contact recreational, agriculture, industrial water supply

B. Standards:

(1) Dissolved oxygen = 6mg/L, fecal coliform = 100/100 mL (geometric mean) or 200/100 mL (single sample), temperature = 20^{o} C, pH = 6.5-8.5, turbidity = 25 NTU, As = 20.5 ug/L, Hg (fish consumption) = 0.051ug/L

(2) Narrative standards include, but are not limited to:

i. Stream Bottom Deposits – Surface waters shall be free from water contaminants from other than natural causes that may settle and have a deleterious effect on the aquatic biota or that will significantly alter the physical or chemical properties of the water or the bottom sediments.

ii. Nuisance Conditions – Plant nutrients or other substances stimulating algal growth from other than natural causes shall not be present in concentrations that produce objectionable algal densities or nuisance aquatic vegetation, or that result in a dominance of nuisance species instream, or that cause nuisance conditions in any other fashion. Phosphorous (P) and nitrogen (N) concentrations shall not reach levels which result in man-induced eutrophication problems. Total P shall not exceed 100 ug/L instream or 50 ug/L in lakes in reservoirs except waters highly laden with natural silts or color which reduce the penetration of light needed for photosynthesis, or in other waters where it can be demonstrated that algal production will not interfere with or adversely affect designated and other attainable uses.

iii. Salinity/Mineral Quality – (TDS, chlorides, and sulfates) existing mineral quality shall not be altered by municipal, industrial, or instream activities, or other water discharges so as to interfere with the designated or attainable uses for a water body. An increase of more than 1/3 over naturally-occurring levels shall not be permitted. Numeric criteria for chlorides at 230 mg/L, for sulfates at 250 mg/L, and for TDS at 500 mg/L shall not be exceeded.

WQR 8.0a

Segment of the Rio Grande that passes through San Juan Pueblo

San Juan Pueblo Standards:

A. Designated Uses: coldwater fishery, warmwater fishery, primary contact ceremonial, primary contact recreational, secondary contact recreational, agriculture, industrial water supply

B. Standards:

(1) Dissolved oxygen = 6mg/L, fecal coliform = 100/100 mL (geometric mean) or 200/100 mL (single sample), temperature = 20^{o} C, pH = 6.5-8.5, turbidity = 25 NTU, As = 20.5 ug/L, Hg (fish consumption) = 0.051ug/L

(2) Narrative standards include, but are not limited to:

i. Stream Bottom Deposits – Surface waters shall be free from water contaminants from other than natural causes that may settle and have a deleterious effect on the aquatic biota or that will significantly alter the physical or chemical properties of the water or the bottom sediments.

ii. Nuisance Conditions – Plant nutrients or other substances stimulating algal growth from other than natural causes shall not be present in concentrations that produce objectionable algal densities or nuisance aquatic vegetation, or that result in a dominance of nuisance species instream, or that cause nuisance conditions in any other fashion. Phosphorous and nitrogen concentrations shall not reach levels which result in man-induced eutrophication problems. Total P shall not exceed 100 ug/L instream or 50 ug/L in lakes in reservoirs except waters highly laden with natural silts or color which reduce the penetration of light needed for photosynthesis, or in other waters where it can be demonstrated that algal production will not interfere with or adversely affect designated and other attainable uses.

iii. Salinity/Mineral Quality – (TDS, chlorides, and sulfates) existing mineral quality shall not be altered by municipal, industrial, or instream activities, or other water discharges so as to interfere with the designated or attainable uses for a water body. An increase of more than 1/3 over naturally-occurring levels shall not be permitted. Numeric criteria for chlorides at 230 mg/L, for sulfates at 250 mg/L, and for TDS at 500 mg/L shall not be exceeded.

WQR 8.0c

Segment of the Rio Grande that passes through Santa Clara Pueblo

Santa Clara Pueblo Standards:

A. Designated Uses: marginal coldwater fishery, warmwater fishery, irrigation, livestock and wildlife, primary contact

B. Standards:

(1) Dissolved oxygen = 6mg/L, fecal coliform = 200/100 mL, temperature = 25^{o} C, pH = 6.6-8.8, turbidity = 25 NTU, TDS = 500 mg/L, As = 360 ug/L

(2) Narrative standards include, but are not limited to:

i. Stream Bottom Deposits – Surface waters shall be free from water contaminants from other than natural causes that may settle and have a deleterious effect on the aquatic biota or that will significantly alter the physical or chemical properties of the water or the bottom sediments.

ii. Nuisance Conditions – Plant nutrients or other substances stimulating algal growth from other than natural causes shall not be present in concentrations that produce objectionable algal densities or nuisance aquatic vegetation, or that result in a dominance of nuisance species instream, or that cause nuisance conditions in any other fashion. Phosphorous and nitrogen concentrations shall not reach levels which result in man-induced eutrophication problems.

iii. Salinity/Mineral Quality – (TDS, chlorides, and sulfates) existing mineral quality shall not be altered by municipal, industrial, or instream activities, or other water discharges so as to interfere with the designated or attainable uses for a water body. An increase of more than 1/3 over naturally-occurring levels shall not be permitted. Numeric criteria for chlorides at 230 mg/L, for sulfates at 250 mg/L, and for TDS at 500 mg/L shall not be exceeded.

WQR 10.1, 10.2, 10.3, 12.0b, 13.0, 14.0

Rio Grande Basin – The main stem of the Rio Grande from the headwaters of Elephant Butte reservoir upstream to Alameda bridge (Corrales Bridge), the Jemez river from the Jemez pueblo boundary upstream to the Rio Guadalupe, and intermittent flow below the perennial reaches of the Rio Puerco and Jemez river which enters the main stem of the Rio Grande.

New Mexico Standards (20.6.4.105):

A. Designated Uses: irrigation, limited warmwater fishery, livestock watering, wildlife habitat, and secondary contact.

B. Standards:

(1) In any single sample: pH shall be within the range of 6.6 to 9.0, and temperature shall not exceed 32.2°C (90°F). The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 1,000/100 mL; no single sample shall exceed 2,000/100 mL (see Subsection B of 20.6.4.13 NMAC)

(3) At mean monthly flows above 100 cubic feet per second (cfs), the mean monthly average concentration for: TDS shall not exceed 1,500 mg/L, sulfate shall not exceed 500 mg/L, and chloride shall not exceed 250 mg/L

(4) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state.

iii. Turbidity – Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

WQR 11.1

Rio Grande Basin – Cochiti Reservoir

New Mexico Standards (20.6.4.112):

A. Designated Uses: livestock watering, wildlife habitat, coldwater fishery, warmwater fishery, and primary contact.

B. Standards:

(1) In any single sample: pH shall be within the range of 6.6 to 9.0, temperature shall not exceed 25°C (77°F), and turbidity shall not exceed 25 NTU. The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 100/100 mL; no single sample shall exceed 200/100 mL (see Subsection B of 20.6.4.13 NMAC)

(3) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the State.

iii. W hen changes in dissolved oxygen, temperature, dissolved solids, sediment or turbidity in a water of the state is attributable to natural causes or the reasonable operation of irrigation and flood control facilities that are not subject to federal or state water pollution control permitting, numerical standards for temperature, dissolved solids content, dissolved oxygen, sediment or turbidity adopted under the Water Quality Act do not apply. The foregoing provision does not include major reconstruction of storage dams or diversion dams except for emergency actions necessary to protect health and safety of the public, or discharges from municipal separate storm sewers.

WQR 11.2, 11.3

Rio Grande Basin – The main stem of the Rio Grande from Angostura diversion works upstream to Cochiti dam.

New Mexico Standards (20.6.4.110):

A. Designated Uses: irrigation, livestock watering, wildlife habitat, secondary contact, coldwater fishery, and v

B. Standards:

(1) In any single sample: pH shall be within the range of 6.6 to 8.8, and temperature shall not exceed 25°C (77°F). The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 200/100 mL; no single sample shall exceed 400/100 mL (see Subsection B of 20.6.4.13 NMAC)

(3) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the State.

iii. Turbidity – Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

WQR 12.0a

Rio Grande at Bernalillo to south boundary of Sandia Pueblo

Sandia Pueblo Standards:

A. Designated Uses: primary contact ceremonial, primary contact recreational, secondary contact recreational, agricultural, industrial

B. Standards:

(1) Temperature = 32.2^{o} C, DO = 5mg/L, pH = 6.0-9.0, As = 17.5ng/L, fecal coliform = 100/100 mL, turbidity = 25 NTU

(2) Narrative standards include, but are not limited to:

i. Stream Bottom Deposits – Surface waters shall be free from water contaminants from other than natural causes that may settle and have a deleterious effect on the aquatic biota or that will significantly alter the physical or chemical properties of the water or the bottom sediments.

ii. Salinity/Mineral Quality – (TDS, chlorides, and sulfates) existing mineral quality shall not be altered by municipal, industrial, or instream activities, or other water discharges so as to interfere with the designated or attainable uses for a water body. An increase of more than 1/3 over naturally-occurring levels shall not be permitted. Numeric criteria for chlorides at 230 mg/L, for sulfates at 250 mg/L, and for TDS at 500 mg/L shall not be exceeded.

iii. Nuisance Conditions – Plant nutrients or other substances stimulating algal growth from other than natural causes shall not be present in concentrations that produce objectionable algal densities or nuisance aquatic vegetation, or that result in a dominance of nuisance species instream, or that cause nuisance conditions in any other fashion. Phosphorous and nitrogen concentrations shall not reach levels which result in man-induced eutrophication problems. Total P shall not exceed 100 ug/L instream or 50 ug/L in lakes in reservoirs except waters highly laden with natural silts or color which reduce the penetration of light needed for photosynthesis, or in other waters where it can be demonstrated that algal production will not interfere with or adversely affect designated and other attainable uses.

WQR 12.0c

Segment of the Rio Grande that passes through Pueblo of Isleta

Isleta Pueblo Standards:

A. Designated Uses: primary contact ceremonial, primary contact recreational, secondary contact recreational, agricultural, industrial

B. Standards:

(1) Temperature = 32.2^{o} C, DO = 5mg/L, pH = 6.0-9.0, As = 17.5ng/L, fecal coliform = 100/100 mL, turbidity = 25 NTU

(2) Narrative standards include, but are not limited to:

i. Stream Bottom Deposits – Surface waters shall be free from water contaminants from other than natural causes that may settle and have a deleterious effect on the aquatic biota or that will significantly alter the physical or chemical properties of the water or the bottom sediments.

ii. Salinity/Mineral Quality – (TDS, chlorides, and sulfates) existing mineral quality shall not be altered by municipal, industrial, or instream activities, or other water discharges so as to interfere with the designated or attainable uses for a water body. An increase of more than 1/3 over naturally-occurring levels shall not be permitted. Numeric criteria for chlorides at 230 mg/L, for sulfates at 250 mg/L, and for TDS at 500 mg/L shall not be exceeded.

iii. Nuisance Conditions – Plant nutrients or other substances stimulating algal growth from other than natural causes shall not be present in concentrations that produce objectionable algal densities or nuisance aquatic vegetation, or that result in a dominance of nuisance species instream, or that cause nuisance conditions in any other fashion. Phosphorous and nitrogen concentrations shall not reach levels which result in man-induced eutrophication problems. Total P shall not exceed 100 ug/L instream or 50 ug/L in lakes in reservoirs except waters highly laden with natural silts or color which reduce the penetration of light needed for photosynthesis, or in other waters where it can be demonstrated that algal production will not interfere with or adversely affect designated and other attainable uses.

WQR 15.1

Rio Grande Basin – Elephant Butte Reservoir

New Mexico Standards (20.6.4.104):

A. Designated Uses: irrigation storage, livestock watering, wildlife habitat, primary contact, and warmwater fishery.

B. Standards:

(1) At any sampling site: pH shall be within the range of 6.6 to 9.0, and temperature shall not exceed 32.2°C (90°F), and turbidity shall not exceed 50 NTU. The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 100/100 mL; no single sample shall exceed 200/100 mL (see Subsection B of 20.6.4.13 NMAC).

(3) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the State.

iii. When changes in dissolved oxygen, temperature, dissolved solids, sediment or turbidity in a water of the state is attributable to natural causes or the reasonable operation of irrigation and flood control facilities that are not subject to federal or state water pollution control permitting, numerical standards for temperature, dissolved solids content, dissolved oxygen, sediment or turbidity adopted under the Water Quality Act do not apply. The foregoing provision does not include major reconstruction of storage dams or diversion dams except for emergency actions necessary to protect health and safety of the public, or discharges from municipal separate storm sewers.

WQR 15.2

Rio Grande Basin – The main stem of the Rio Grande from the headwaters of Caballo lake upstream to Elephant Butte dam and perennial reaches of tributaries to the Rio Grande in Sierra and Socorro counties. (Flow in this reach of the Rio Grande main stem is dependent upon release from Elephant Butte Dam.)

New Mexico Standards (20.6.4.103):

A. Designated Uses: fish culture, irrigation, livestock watering, wildlife habitat, marginal coldwater fishery, secondary contact, and warmwater fishery.

B. Standards:

- **(1)** At any sampling site: pH shall be within the range of 6.6 to 9.0, and temperature shall not exceed 25°C (77°F). The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.
- **(2)** The monthly geometric mean of fecal coliform bacteria shall not exceed 1,000/100 mL; no single sample shall exceed 2,000/100 mL (see Subsection B of 20.6.4.13 NMAC).
- **(3)** Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:
  - i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.
  - ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the State.
  - iii. Turbidity – Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

WQR 16.1

Rio Grande Basin – The main stem of the Rio Grande from one mile below Percha dam upstream to the headwaters of Caballo reservoir including Caballo reservoir. (Sustained flow in the Rio Grande below Caballo reservoir is dependent on release from Caballo reservoir during irrigation season; at other times of the year, there may be little or no flow.)

New Mexico Standards (20.6.4.102):

A. Designated Uses: irrigation, livestock watering, wildlife habitat, warmwater fishery, and primary contact.

B. Standards:

- **(1)** At any sampling site: pH shall be within the range of 6.6 to 9.0, and temperature shall not exceed 32.2°C (90°F), and turbidity shall not exceed 50 NTU. The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 100/100 mL; no single sample shall exceed 200/100 mL (see Subsection B of 20.6.4.13 NMAC).

(3) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the State.

iii. W hen changes in dissolved oxygen, temperature, dissolved solids, sediment or turbidity in a water of the state is attributable to natural causes or the reasonable operation of irrigation and flood control facilities that are not subject to federal or state water pollution control permitting, numerical standards for temperature, dissolved solids content, dissolved oxygen, sediment or turbidity adopted under the Water Quality Act do not apply. The foregoing provision does not include major reconstruction of storage dams or diversion dams except for emergency actions necessary to protect health and safety of the public, or discharges from municipal separate storm sewers.

WQR 16.2

Rio Grande Basin – The main stem of the Rio Grande from the international boundary and water commission (IBWC) sampling station above American dam upstream to one mile below Percha dam. (Sustained flow in the Rio Grande below Caballo reservoir is dependent on release from Caballo reservoir during the irrigation season; at other times of the year, there may be little or no flow).

New Mexico Standards (20.6.4.101):

A. Designated Uses: irrigation, limited warmwater fishery, livestock watering, wildlife habitat, and secondary contact

B. Standards:

(1) At any sampling site: pH shall be within the range of 6.6 to 9.0, and temperature shall not exceed 34°C (93.2°F). The use-specific numeric standards set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of fecal coliform bacteria shall not exceed 1,000/100 mL; no single sample shall exceed 2,000/100 mL (see Subsection B of 20.6.4.13 NMAC).

(3) At mean monthly flows above 350 cfs, the monthly average concentration for: TDS shall not exceed 2,000 mg/L, sulfate shall not exceed 500 mg/L, and chlorides shall not exceed 400 mg/L.

(4) Narrative standards are those set forth in section 20.6.4.12 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters. These include, but are not limited to:

i. Bottom Deposits – Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

ii. Plant Nutrients – Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the State.

iii. Turbidity – Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

WQR 17.1, 17.2

Rio Grande above and below International Dam

Texas Water Quality Standards (Segments 2314 and 2308):

A. Designated Uses: contact recreation, public water supply

B. Standards:

(1) Temperature = 33.3^{o} C (WQR 17.1) and 33.9 ^{o} C (WQR 17.2), DO = 5mg/L, TDS = 1800 mg/L (WQR 17.1) and 1400 mg/L (WQR 17.2), pH = 6.5-9.0, As = 360 ug/L, Hg (fish tissue) = 0.0122 ug/L, fecal coliform = 126/200 mL.

(2) Narrative standards include, but are not limited to:

i. Surface water shall be essentially free of floating debris and suspended solids that are conducive to producing adverse responses in aquatic organisms or putrescible sludge deposits or sediment layers which adversely affect benthic biota or any lawful uses.

ii. Surface waters shall be essentially free of settleable solids conducive to changes in flow characteristics of stream channels or the untimely filling of surface water in the state. This provision does not prohibit dredge and fill activities which are permitted in accordance with the Federal Clean Water Act.

iii. Nutrients from permitted discharges or other controllable sources shall not cause excessive growth of aquatic vegetation which impairs an existing, attainable, or designated use. Site-specific nutrient criteria, nutrient permit limitations, and/or separate rules to control nutrients in individual watersheds will be established where appropriate after notice and opportunity for public participation and proper hearing.

1.3 Water Quality Resource Team Objectives

Principal issues addressed by the Water Quality Resource Team included qualitative and quantitative measures that would best preserve water quality within the Rio Grande Basin. The team's objectives were to:

- Identify existing State and Tribal water quality standards and jurisdictional issues in the study area
- Document water quality in lentic and lotic systems
- Document historic and current river and reservoir water quality

- Correlate water quality data with historic reservoir operations
- Define historic seasonal changes in water quality on the Rio Grande (1975-2001)
- Estimate changes in water quality projected to occur under EIS alternatives to current water operations in the Rio Grande Basin
- Define cumulative effects on water quality from EIS alternatives
- Compare estimated water quality effects under EIS alternatives to applicable State and Tribal water quality standards

After review of all applicable standards, the WQRT developed a set of water quality resource indicators for both reservoirs and river reaches. Indicators were developed by preliminarily assessing the availability of water quality data in the project area and by identifying specific water quality constituents that were most likely to be affected by reservoir operations. Generally, constituents with numeric standards were selected. However, additional constituents were included if it was determined that they posed a specific human health threat, were uniquely influenced by reservoir operations, or were subject to antidegradation policies. The water quality constituents selected were those with adequate data available for analysis, most affected by reservoir operations, the best indicators of water quality, and of most interest to the Rio Grande watershed:

- Water Temperature
- Dissolved Oxygen
- Suspended Sediment/Turbidity
- Salinity/Specific Conductivity
- Total Dissolved Solids
- pH
- Arsenic
- Mercury
- Nutrients
- Fecal Coliform

2.0 Water Quality Conditions in Lotic and Lentic Systems

Water quantity and quality are more critical in arid to semi-arid environments than perhaps anywhere else due to the scarcity of water (RM-4 Brooks et al. 1997). Generally, water quality in water bodies, whether lotic (moving, as in rivers and streams) or lentic (standing, as in lakes and reservoirs) refers to the temperature of the water and the amount of dissolved gases and solids, suspended solids, pathogenic organisms, and hydrogen ions (H+) within the water (RM-5 Dingman 1994). Water is considered to be polluted when the concentration of a constituent may adversely affect or alter the aquatic ecosystem or violate any specified water quality standard. In a riverine environment, water quality is negatively affected by inputs to and losses from the stream, whether anthropogenic or natural, that degrade the environment and add pollutants. Water quality in reservoirs is subject to natural degradation from eutrophication and anthropogenic impacts that could speed eutrophication.

The impacts of reservoir operations on surface water quality, both within the reservoirs and in the streams they modify, are of increasing concern to water managers, planners, scientists, and landowners faced with balancing the storage and delivery of water for agricultural, urban, industrial, and environmental use. Water impoundments can create a unique ecosystem with altered water quality conditions both in the reservoir and downstream. Drainage basin characteristics influence both riverine and reservoir water quality, as inflows to a reservoir plays a significant role in determining reservoir water quality dynamics. Dissimilar water quality characteristics are often found at the point of inflow, but mixing nearly always occurs in a reservoir, creating widely varying water quality conditions at the reservoir outflow. Reservoir operations, including flood control and irrigation storage, can also impact water quality by altering constituent composition and downstream transport of materials that enter the reservoirs from upstream river reaches.

2.1 Water Quality Constituents

The U.S. Geological Survey (USGS) has conducted the majority of the water quality research in the Rio Grande watershed. Additional water quality data have been collected by numerous other entities including the States of Colorado, New Mexico, and Texas, the U.S. Environmental Protection Agency (EPA), the International Boundary and Water Commission (IBWC), and various other local, state, and federal entities. The following discussion describes the most significant water quality constituents in the lotic and lentic systems of the Rio Grande Basin and assesses their impacts.

2.1.1 Surface Water Temperature

Riverine water temperature varies seasonally and daily and from location to location, based on factors that include short-term and long-term climate, altitude, extent of streamside vegetation, and relative importance of groundwater inputs (RM-6 Allan 1995). Water temperature fluctuations closely follow seasonal trends in air temperature. However, spring-fed and headwater streams with constant groundwater inflow have stable water temperatures throughout the year, even with large changes in air temperature. Water temperature in temperate rivers ranges annually between 0°C and 25°C. Desert streams can reach temperatures as high as 40°C, while headwater and spring-fed streams at high elevations rarely exceed 15°C (RM-6 Allan 1995). Since water follows gravity from higher to lower elevations, temperatures are generally lowest in headwater reaches and steadily increase to warmer temperatures in lower reaches.

Daily variation in lotic water temperature depends on stream/river size, weather conditions, and the extent of riparian vegetation. Because of the volume of water involved, large rivers have little daily variation in water temperature. Small headwater and spring-fed streams also show little daily variation due to shading and constant groundwater input. Waterways with significant amounts of riparian vegetation will be shaded and thus maintain relatively low water temperatures. However, unshaded streams of intermediate size may have daily temperature fluxes of up to 10°C (RM-6 Allan 1995).

Water temperature plays a crucial role in the presence or absence and distribution of aquatic flora and fauna in riverine environments. For many faunal species, large water temperature fluxes and/or a higher mean temperature can inhibit particular stages in the life cycle and thus decrease numbers. These changes in mean temperature are especially detrimental to fish populations (RM-7 Horne and Goldman 1994). Existing species may be replaced, which may ultimately alter the quality of local water.

Water impoundment behind dams can alter water temperature trends even in large rivers, especially downstream of the dam. Reservoirs created behind large dams produce stratified thermal regimes similar to those in lakes, in which the surface layer will be warmer than the river water before impoundment and the deep water will be much colder. Since the temperature of the river below the dam depends on the temperature of release water, surface releases (of reservoir water that is close to the surface) will cause higher than average river water temperatures, and bottom releases will cause much colder average water temperatures (RM-6 Allan 1995). Such thermal regime changes can alter the ecosystem below the dam.

Not only biological processes but chemical processes as well depend on temperature. Temperature regime changes within a reservoir are the result of the combined effects of natural processes and reservoir operations, especially inflows and outflows (RM-8 Dasic and Djordjevic 2002). Direct absorption of solar energy is the primary mechanism responsible for heating the water in a reservoir (RM-9 Wetzel 1983). Sediments, either settled or suspended, also absorb much of the incoming solar radiation. The sediments have the ability to absorb heat during warmer periods and transmit that heat to the water during winter, and may play a much more vital role in thermal absorption in small reservoirs than in large ones (RM-10 Likens and Johnson 1969).

Stratification is a seasonal phenomenon that is driven by summer temperatures substantially raising the temperature of the upper water layers. In typical thermal stratification of a reservoir, the impounded water becomes separated into three strata: epilimnion, metalimnion, and hypolimnion (**Figure M-1.1**). As water temperature increases, its density decreases (Figure **M-1.2**), and surface waters warmed by insolation will thus remain at the surface of the water body, forming the epilimnion, while the denser, cooler water settles at the bottom, forming the hypolimnion. The intermediate layer is the metalimnion, and the layer of rapid temperature change separating the two layers (epilimnion and hypolimnion) is called the thermocline (RM-11 Smith 1990).

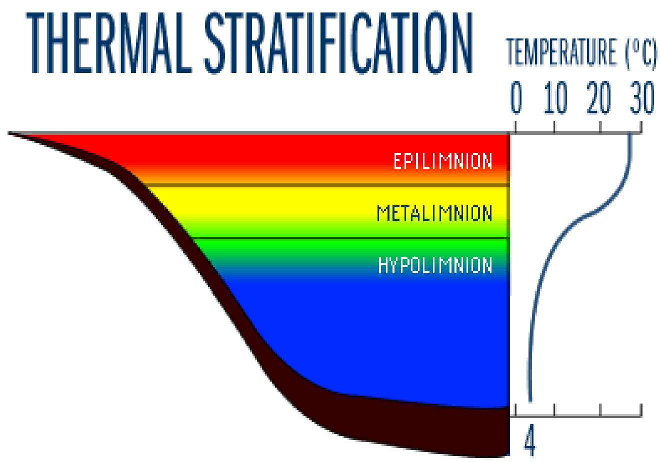

Figure M-1.1. Typical stratification of a reservoir (courtesy http://www.shorelandmanagement.org).

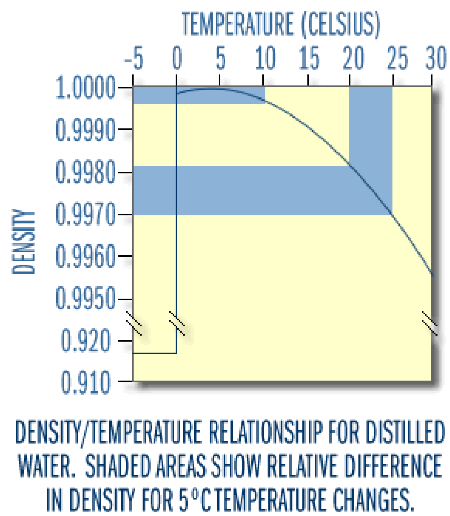

Figure M-1.2. Density and temperature relationships in bodies of water (courtesy http://www.shorelandmanagement.org).

In the fall, with lowered heat input into the reservoir system, the epilimnion waters cool, become denser, and sink. Stratification is lost as the reservoir water mixes and turns over, restoring a more uniform temperature throughout the water body. In the spring, with the influx of snowmelt, stratification will break down further, and any slight wind will initiate turnover within the system, mixing nutrients and oxygen. Spring or fall turnover may last for weeks in larger reservoirs, affecting water quality not only in terms of temperature but through changes in nutrient distribution, turbidity, and dissolved oxygen (RM-9 Wetzel 1983).

2.1.2 Dissolved Oxygen and Carbon Dioxide

Dissolved oxygen (DO) and carbon dioxide (CO_2) occur in significant amounts in streams and rivers. Exchange between the water surface and the atmosphere, coupled with stream turbulence and organism respiration, supplies the water with these dissolved gases. The amount of dissolved oxygen and carbon dioxide depends on pressure, surface water temperatures, altitude, and the synergistic effects of other constituents (RM-11 Smith 1990). Cold, fast-flowing waters have higher dissolved oxygen levels, while warm, slow-moving waters have lower oxygen content. In flowing water, mixing takes place along the air-water interface, where oxygen-rich water is constantly being replaced by water that contains less oxygen through mixing and turbulence. Stagnant water goes through less internal mixing, except during seasonal turnover, and dissolved oxygen values are lower throughout the column of water. Since the water is not moving, dissolved oxygen values decrease due to respiration, decomposition of organic matter, and increases in water temperature. Runoff from agricultural lands and sewage effluent can also contribute to lower dissolved oxygen levels and promote eutrophication.

Small, turbulent streams with limited pollution maintain stable dissolved oxygen and carbon dioxide levels via diffusion, but high biological activity in larger rivers alters oxygen and carbon dioxide levels through photosynthetic and organic respiration processes. In eutropic (nutrient rich) systems with high levels of photosynthetic organisms, oxygen is elevated and carbon dioxide is reduced during the day, when photosynthesis takes place; during the night the reverse occurs as respiration dominates (RM-6 Allan 1995). Organic pollution can greatly increase microbial levels, with a concomitant increase in the demand for oxygen, causing low oxygen levels, and increased respiration, elevating carbon dioxide levels. Concentrations of dissolved oxygen vary due to synergistic reactions with other constituents. For example, dissolved oxygen solubility increases with decreasing salinity levels.

Dissolved oxygen is essential to the life cycle of aerobic aquatic organisms and can be a critical environmental variable, as biotas of lotic waters constantly depend on its availability (RM-12 Hynes 1970). Prolonged exposure to low dissolved oxygen levels will increase an organism's susceptibility to environmental stresses (RM-5 Dingman 1994). In reservoirs, problems occur seasonally or synergistically when dissolved oxygen reacts to changes in other constituent levels. Low dissolved oxygen concentrations can lead to releases in reservoirs—and thus into downstream waters—of such gases as ammonia (H_3N), methane (CH_4), and hydrogen sulfide (H_2S) (RM-8 Dasic and Djordjevic 2002), which may create a toxic environment for aquatic organisms. Levels of dissolved oxygen are governed by anthropogenic inputs and by natural processes, both atmospheric and photosynthetic. Dissolved oxygen will also vary by season and with changes in stratification within the reservoir (RM-13 Tchobanoglous and Schroeder 1987).

Dissolved oxygen levels in reservoirs are commonly highest in water near the surface, where mixing and photosynthetic processes occur. However, at the beginning of the summer, the colder hypolimnion will contain more dissolved oxygen than the surface layers. As the summer progresses, microbial decomposition increases, resulting in an oxygen-deficient hypolimnion and higher dissolved oxygen levels near the reservoir surface. This process may be accelerated by an influx of nutrients into the reservoir; creating a eutrophic state and further depleting dissolved oxygen in the hypolimnion (RM-11 Smith 1990).

Two other considerations related to dissolved oxygen are biological oxygen demand (BOD) and chemical oxygen demand (COD). BOD reflects the concentration of organic wastes that have the ability to consume dissolved oxygen, or the amount of oxygen consumed during the breakdown of organic matter within the water. COD is a measure of pollutant loading using oxidation agents (chemical oxidation). COD is not necessarily a good indicator of oxygen demands within waters (RM-4 Brooks et al. 1997).

2.1.3 Total Dissolved Solids and Salinity

The measure of total dissolved solids (TDS) represents the sum of all major dissolved ion concentrations in freshwater. TDS in most streams and rivers is dominated by the weathering of sedimentary rock, but varies widely due to many natural and anthropogenic sources. Common ions include calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), silica, bicarbonate (CHO_3^--), chloride (Cl^--), and sulfate (O_4S^{-2}-$_2$). Pollution from domestic sewage, fertilizers, road salt, and mining activities can substantially increase sodium, chloride, and sulfate while slightly increasing other ions. Specific conductivity, a measure directly related to TDS, is a measure of electrical conductance of ions, and an approximate predictor of total dissolved ions. When surface flows decrease, the concentration of TDS may increase, increasing conductivity. *Salinity* is often used interchangeably with TDS. Generally, surface water TDS concentrations in fluvial systems increase with the length of time the water has been in the hydrologic system (RM-1 Levings et al. 1998). Processes such as evapo-transpiration, transpiration, and dissolution of minerals increase the concentration of dissolved solids.

Sodium chloride (NaCl), salt, concentrations are expected to be high in arid to semi-arid areas where evaporation exceeds precipitation. As water evaporates from existing water bodies, salt concentrations increase. In addition, because precipitation itself contains traces of NaCl, evaporation after a precipitation event deposits salt in soils. These salts may be transported in irrigation return flow or in overland flow during rainstorm runoff (RM-14 Pefetti and Terrel 1989). Additional salts are added to waterways from the weathering of minerals in soils (RM-15 Walton and Ohlmacher 1998; RM-16 Wilson 1999).

Generally, processes that influence TDS, conductance, and salinity are the same in lentic and lotic systems. In reservoirs, waters with high TDS levels (saline water) will sink to the hypolimnion because of their density and will not mix well with other reservoir water, commonly leading to decreased dissolved oxygen levels in the hypolimnion (RM-17 Gower 1980).

2.1.4 pH

Reservoir pH values that are excessively high or low can have adverse affects on water quality (RM-5 Dingman 1994). The acidic or basic condition of a water body is determined by measuring the concentration of hydrogen ions (RM-6 Allan 1995) and is commonly expressed as pH. A pH of 7 is the neutral condition. A pH greater than 7 is alkaline and occurs when carbonate (CO_3^{-2}-$_2$) and bicarbonate are present. A pH less than 7 is acidic. Variation in pH is due to natural and anthropogenic inputs and synergistic affects. As flow decreases, pH can increase with increased concentrations of total dissolved solids. An increase in pH commonly signals increased ammonia (H_3N) levels (RM-18 U.S. EPA 1987). At pH values above 9, ammonia can be very toxic to organisms in high enough concentrations (RM-19 NRC 1979). Carbon dioxide can also affect pH values (RM-4 Brooks et al. 1997). Acidification of aquatic systems inhibits microbial activity, reducing decomposition and nutrient cycling. This can lead to a decrease in the number of plants and/or invertebrates within the system, eventually affecting higher organisms as well. As pH decreases, the increased acidity of the water may also release toxic metals that would otherwise be bonded to sediment. The heavy metal ions may dissolve into solution and become available for uptake by various organisms (RM-20 Connell and Miller 1984), becoming lethal if uptake is too great.

Water temperature can also affect pH. Rainwater is naturally acidic, but soil neutralizes the acidity over time. However, industrial emissions have increased the acidity of rain, thus lowering the pH in many freshwaters. Values below 5 or above 9 are harmful to most aquatic organisms. The acidity or alkalinity of water can also act synergistically with other organic material and carbon (C) to affect water quality. Organic material can lower pH, while the calcium bicarbonate ($C_2H_2CaO_6$) content of freshwater normally determines the pH balance (RM-6 Allan 1995).

2.1.5 *Turbidity and Suspended Sediments*

Turbidity is a measure of the degree to which light can travel through inorganic particles and suspended organics that are scattered in the water column. Turbidity can greatly affect water quality and induce changes that may alter the composition of an aquatic community (RM-21 Wilber 1983). For example, as a result of higher turbidity caused by a large volume of suspended sediment, sunlight may not be able to penetrate deep into the water, altering primary production in the uppermost layers (RM-22 McCabe and Sandretto 1985). Reduced light penetration can suppress photosynthetic activity of algae, macrophytes, and phytoplankton, decreasing the availability of photosynthetic organisms as food sources for invertebrates, which may in turn lead to an overall decline in fish and other aquatic populations.

Suspended sediment refers to sand- to clay-sized particles suspended in the water column and is generally a function of stream or river size, surrounding land use conditions, geology and erodibility of the drainage basin, and discharge and water velocities. An increase in streamflow velocity related to natural occurrences such as snowmelt or ephemeral storm inflows, or anthropogenic changes in reservoir operations and wastewater inflows, can result in higher concentrations of suspended sediment within a system (RM-3 Moore and Anderholm 2002).

Reservoirs may greatly alter sediment concentration and turbidity within a river system. Dams and reservoirs can serve as settling basins, greatly reducing turbidity (RM-23 Crossman 1998) and affecting transport and deposition of sediments, nutrients, and chemicals downstream. Suspended sediments within a reservoir usually consist of the smallest particles, predominantly silts and clays (RM-24 Dunne and Leopold 1978). However, dams also interrupt the downstream transport of larger particles, including sands and gravels.

2.1.6 Nutrients and Heavy Metals

The term *nutrient* refers to any inorganic material that is necessary for life. Nutrients in lotic water occur as ions or dissolved gases and are affected by chemical, physical, and biological processes. An example of a physical process is the adsorption of nutrients to inorganic surfaces such as suspended sediments; a chemical process is oxidation; and two major biological processes that affect nutrients are assimilation and excretion (RM-6 Allan 1995). Nutrients in streams and rivers vary widely based on location and season, geology, rainfall, stream size, surrounding landscape patterns and land use, and human influence. Nutrients in small streams are determined primarily by local geology and organic material in the watershed. Nutrient loads are often modified by human-related activities such as industrial emissions, sewage effluent, agricultural and urban runoff, and water impoundments. Common nutrients in lotic waters include: carbon, nitrogen (N), phosphorus (P), silica, and many ions and trace elements.

Heavy metal loading is directly correlated with the amount of sediment being transported into the waterway. Agricultural erosion and runoff from construction sites and unvegetated areas are primary sources of both sediments and metals (RM-25 Morton 1986; RM-22 McCabe and Sandretto 1985). Other primary sources of heavy metal and nutrient loading include runoff from mining operations (past and present), road construction, and wildfire burn areas.

Nitrogen and phosphorus are primary nutrients found in both lentic and lotic waters. The levels and transport of these nutrients vary naturally based on season, climate, discharge, floods, atmospheric diffusion, geology of the watershed, and biological input. For example, streams that are fed by snowmelt have large fluctuations in discharge, and therefore a large flux in nutrient concentrations and transport. Anthropogenic sources include sewage effluent, agricultural and urban runoff, and industrial emissions alter nitrogen and phosphorus levels. For example, nitrogen often increases in agricultural and urban areas, while phosphorus generally increases in sewage effluent areas. Combinations of factors in a watershed determine fluctuations of these nutrients. Nitrate (HNO_3) levels are controlled by pH, biological nitrogen fixation and denitrification, freezing and thawing cycles, runoff from fires, erosion, and presence or absence of vegetation.

Nitrogen can occur in reservoirs in various forms. Most nitrogen input into a reservoir is considered to come from surrounding land, not the atmosphere. Anthropogenic nitrogen is directly related to agricultural fertilizers, sewage and industrial waste runoff, and atmospheric pollution. On a localized scale, grazing can influence nitrogen transformation rates and microbial populations (RM-9 Wetzel 1983). Nitrogen, unlike oxygen and carbon dioxide, is not very soluble in water. Maximum concentrations are often found during the winter when solubility increases with colder temperatures (RM-9 Wetzel 1983). High concentrations of nitrates can stimulate algal growth (RM-4 Brooks et al. 1997). If phosphorus is present, small amounts of nitrates can stimulate large algal blooms. Cycling of nitrogen may be adversely impacted by retention time, reservoir elevation fluctuations, and releases from the reservoir.

The impact of phosphorus on lentic and lotic systems has been studied intensively. Lakes and reservoirs act as phosphorus sinks, playing a major role in biological metabolism and reservoir productivity. Phosphorus may enter the reservoir through flowing water (inflow) and leave the system through flowing water (outflow). Phosphorus can also reach reservoirs through precipitation events, although concentrations in precipitation are extremely low, usually lower than the amount of nitrogen. The amount of phosphorus entering reservoirs is directly related to the amount of phosphorus in soils and geology, topography (slope), and vegetation. The addition of phosphorus can substantially change the quality of water, and can induce eutrophication. Eutrophication results in an increase in algae and biomass (RM-4 Brooks et al. 1997) when high levels of phosphorus and nitrogen are input into the reservoir system. However, very low phosphorus levels also limit biological productivity.

Reservoir sediments generally contain high levels of phosphorus. When sediments are disturbed, phosphorus is released and mixes throughout the water body. Phosphorus stored in the uppermost layers of the reservoir bottom sediments is subject to bioturbation and chemical transformations. The reducing conditions often present in a hypolimnion during winter months may induce the release of phosphorus from sediments, which may stimulate algal blooms (RM-26 Dickson et al. 1982). If all the phosphorus within a reservoir system is used, plant growth will cease, no matter how much nitrogen is available (RM-24 Dunne and Leopold 1978).

Algal production is directly correlated with the levels of both nitrogen and phosphorus in a reservoir. If the nitrogen-to-phosphorus ratio (N:P) is above 10:1, the potential for an algal bloom increases drastically (RM-27 Schindler 1978; RM-28 Jaworski 1981). Although algal blooms generally do not pose direct health effects, certain species of algae can produce exotoxins that may be harmful to various aquatic life. An abundance of algae will shade deeper waters and prevent normal photosynthetic activity from occurring (RM-29 Dennison et al. 1993), a decline in essential habitat that can negatively affect the entire ecosystem.

2.1.7 Fecal Coliform

Fecal matter can be deposited directly in reservoirs and waterways via sewage discharges and wildlife, or indirectly from groundwater, sediments, and stormwater overland or channel flow (RM-30 Weiskel *et al.* 1996; RM-31 Wakelin et al. 2003).

2.1.8 Arsenic

Arsenic (As) in surface water can be the result of natural processes or anthropogenic activities. Arsenic is found in water as organic and inorganic compounds. Inorganic compounds include arsenite (As_4O_6) and arsenate (AsH_3O_4); arsenite is ten times more toxic than arsenate. Anthropogenic sources include pesticides, industrial compounds, and fertilizers.

2.1.9 Mercury

Mercury (Hg) is a highly toxic element that is found both naturally and athropogenically in the environment. Elevated levels of mercury can make fish toxic to eat. At high concentrations, mercury can cause birth defects and nerve tissue degeneration (RM-32 Johnson 1995). The toxic effects of mercury depend on its chemical form. Methylmercury (CH_3Hg^++), the most toxic form, can be traced to metal processing, medical wastes, and atmospheric deposition from activities such as the burning of coal (RM-33 USGS 2000). Once mercury is in the atmosphere, it is disseminated and can circulate for a number of years before being deposited into waterways. Natural sources of mercury include volcanic eruptions, geologic deposits, and thermal hot springs. Most water, soil, and rock contain small amounts of mercury (RM-33 USGS 2000).

2.1.10 Sulfur and Hydrogen Sulfide

Sources of sulfur (S) in reservoirs include contributions from local geology, fertilizers, and industrial emissions. Sulfates (O_4S^{-2}-$_2$) may exist in precipitation. Sulfur can have a negative impact on water quality when large amounts of hydrogen sulfide (H_2S) are added to the system by industrial or biogenic sources. Hydrogen sulfide is very soluble in water and generally is found to be present in waters with pH values below 7. Nriagu and Hem (**M-34** 1978) found that an increase in sulfides tends to lower pH.

3.0 Selected Constituents of Water Quality in the Rio Grande Basin: Historic Trends and Current Conditions

The WQRT compiled a database of water quality records for the Rio Grande, its tributaries, and its mainstem reservoirs. Sources for the data were the U.S. Geological Survey (USGS), U.S. Environmental Protection Agency (EPA), International Boundary and Water Commission (IBWC), and New Mexico Environment Department (NMED). **Tables M-3.1-3.5** summarize the compiled data. USGS data were the most extensive, but were not always available. A few gages had large data gaps, and some had no data at all. Once datasets were compiled, analysis methods and modeling techniques were formulated (see Chapter 4). Water quality constituents, USGS gages, and specific reaches, or stream sections, were identified to analyze historic trends and current conditions in the Rio Grande Basin. To better understand these trends and conditions, the WQRT developed a series of objectives:

- Develop statistical correlations between constituents
- Identify data availability
- Identify data gaps
- Collect existing information and reports on water quality in the Rio Grande
- Collect existing information and reports on water quality in reservoirs of the Rio Grande
- Develop long-term and seasonal trend data to better understand how constituents change geographically and temporally

3.1 Data Availability and Analysis

3.1.1 Data Availability

A comprehensive, basin-wide analysis of water quality data from 1975 to the present identified gaps in the data and characterized conditions within the Basin over time. Reaches of the Rio Grande with adequate data were selected to determine the relationships between surface water quality and reservoir operations. At each selected location, correlation statistics were used to derive relationships between water quality constituents and operations.

Table M-3.1 shows the number of total records by constituent for the mainstem Rio Grande and its tributaries. The purpose of the table is to identify both data gaps and data abundance. *Reach Type* indicates whether the data are related to gages along the Rio Grande mainstem (e.g., Otowi, San Acacia) or on tributaries. The table reflects data collected at USGS gages from 1975 to 2001, with the potential of approximately 9,860 days worth of data for each constituent. Constituents analyzed include turbidity; dissolved oxygen (DO); dissolved oxygen percent saturation (% DOsat); pH; salinity; specific conductivity (SC); air temperature; water temperature; total dissolved solids (TDS); fecal coliform; total coliform; arsenic (As); hydrogen sulfide (H_2S); mercury (Hg); and suspended sediments (Susp Sed). The table shows that there are large gaps in the data for salinity and hydrogen sulfide, two constituents that are of primary concern in the Southern Section of the Rio Grande Basin.

Table M-3.1. Number of Total Records (Data Availability) by Constituent for the Mainstem and Tributaries of the Rio Grande

Reach Type	Turbidity	DO	%DOsat	pH	Salinity	SC	Air Temp	Water Temp
Mainstem	1137	2431	1150	4584	1	4563	1997	6455
Tributary	34	175	141	584	0	951	173	1203

Reach Type	TDS	Fecal Coliform	Total Coliform	As	H_2S	Hg	Susp Sed
Mainstem	4688	983	170	623	0	427	4272
Tributary	955	41	10	57	0	11	731

Table **M-3.2** indicates the number of total records by constituent for the five primary river gage sections: Northern, Chama, Central, San Acacia, and Southern. The Northern Section consists of gages along headwater tributaries of the Rio Grande and those to the north of Otowi along the mainstem Rio Grande. The Chama Section includes four gages: Above Abiquiu, Below Abiquiu, and Chamita on the Rio Chama, and Otowi on the Rio Grande. The Central Section consists of all the gages from below Cochiti Dam to Bernardo. The San Acacia Section includes the gages at San Acacia and San Marcial. The Southern Section includes principal gages from below Elephant Butte Dam to Fort Quitman, Texas.

At least some data gaps were identified for each water quality constituent and river section. There were data gaps in all river sections for hydrogen sulfide, and in all but one for salinity. Data were also often lacking for mercury and total fecal coliform loads. Overall, the Northern Section had the fewest available data, while the San Acacia Section had the most. Data were adequate for water temperature, total dissolved solids, specific conductivity, and dissolved oxygen in each river section.

Tables M-3.3a through M-3.3e identify the number of total records by constituent for the primary gages in each river section, by subreach and gage number (Station ID). The data shown in these tables were used to analyze current conditions along the Rio Grande and contributing waterways and to model input data.

Table M-3.2. Number of Total Records (Data Availability) by Constituent for the Five Primary River Sections

Section	Turbidity	DO	%DOsat	pH	Salinity	SC	Air Temp	Water Temp
Northern	207	513	221	672	0	659	143	726
Chama	183	472	278	1237	1	1601	364	1499
Central	83	320	235	774	0	859	508	1661
San Acacia	318	540	264	1390	0	1614	684	2606
Southern	380	761	293	1095	0	781	471	1166

Section	TDS	Fecal Coliform	Total Coliform	As	H_2S	Hg	Susp Sed
Northern	680	181	56	122	0	96	394
Chama	1608	208	49	140	0	77	1191
Central	860	135	0	106	0	52	1213
San Acacia	1615	257	28	126	0	103	1953
Southern	880	243	47	186	0	110	252

Table M-3.3a. Number of Total Records by Constituent for the Primary Northern Section Gages

Station Name	Reach ID	Station ID	Section	Reach Type	Turbidity	DO	%DOsat	pH	Salinity
Rio Grande near Lobatos, CO	01.4	8251500	Northern	Main	110	371	125	474	0
Rio Grande below Taos Junction	03.3	8276500	Northern	Main	97	142	96	198	0

Station Name	SC	Air Temp	Water Temp	TDS	Fecal Coliform	Total Coliform	As	H_2S	Hg
Rio Grande near Lobatos, CO	465	39	524	478	111	56	80	0	63
Rio Grande below Taos Junction	194	104	202	202	70	0	42	0	33

Table M-3.3b. Number of Total Records by Constituent for the Primary Chama Section Gages

Station Name	Reach ID	Station ID	Section	Reach Type	Turbidity	DO	%DOsat	pH	Salinity	SC
Rio Chama above Abiquiu	06.2	8286500	Chama	Trib	9	12	0	5	0	107
Rio Chama below Abiquiu	07.2	8287000	Chama	Trib	0	6	0	7	0	107
Rio Chama near Chamita	07.3	8290000	Chama	Trib	25	130	115	319	0	452
Rio Grande at Otowi	09.0	8313000	Chama	Main	149	324	163	906	1	935

Station Name	Air Temp	Water Temp	TDS	Fecal Coliform	Total Coliform	As	H_2S	Hg	Susp Sed
Rio Chama above Abiquiu	5	214	107	0	5	0	0	0	209
Rio Chama below Abiquiu	0	194	107	0	0	0	0	0	191
Rio Chama near Chamita	92	499	456	41	5	34	0	11	312
Rio Grande at Otowi	267	592	938	167	39	106	0	66	479

Table M-3.3c. Number of Total Records by Constituent for the Primary Central Section Gages

Station Name	Reach ID	Station ID	Section	Reach Type	Turbidity	DO	%DOsat	pH	Salinity	SC
Rio Grande at San Felipe	10.2	8319000	Central	Main	51	176	93	181	0	182
Jemez River below Jemez Canyon Dam	11.3	8329000	Central	Trib	0	27	26	253	0	285
Rio Grande at Albuquerque	12.0.b	8330000	Central	Main	18	45	44	77	0	95
Rio Grande near Bernardo	13.0	8332010	Central	Main	14	72	72	263	0	297

Station Name	Air Temp	Water Temp	TDS	Fecal Coliform	Total Coliform	As	H_2S	Hg	Susp Sed
Rio Grande at San Felipe	188	219	183	132	0	51	0	30	184
Jemez River below Jemez Canyon Dam	76	296	285	0	0	23	0	0	19
Rio Grande at Albuquerque	98	598	95	3	0	13	0	9	553
Rio Grande near Bernardo	146	548	297	0	0	19	0	13	457

Table M-3.3d. Number of Total Records by Constituent for the Primary San Acacia Section Gages

Station Name	Reach ID	Station ID	Section	Reach Type	Turbidity	DO	%DOsat	pH	Salinity	SC
Conveyance Channel at San Acacia	14.0	8354800	San Acacia	Main	33	76	10	88	0	92
Floodway at San Acacia	14.0	8354900	San Acacia	Main	20	92	78	103	0	112
Conveyance Channel at San Marcial	14.0	8358300	San Acacia	Main	61	182	85	675	0	745
Floodway at San Marcial	14.0	8358400	San Acacia	Main	204	190	91	524	0	665

Station Name	Air Temp	Water Temp	TDS	Fecal Coliform	Total Coliform	As	H_2S	Hg	Susp Sed
Conveyance Channel at San Acacia	136	451	92	67	0	6	0	6	358
Floodway at San Acacia	100	588	113	60	0	32	0	24	589
Conveyance Channel at San Marcial	160	614	745	44	26	36	0	33	415
Floodway at San Marcial	288	953	665	86	2	52	0	40	591

Table M-3.3e. Number of Total Records by Constituent for the Primary Southern Section Gages

Station Name	Reach ID	Station ID	Section	Reach Type	Turbidity	DO	%DOsat	pH	Salinity	SC
Rio Grande below Elephant Butte	15.2	8361000	Southern	Main	123	72	1	132	0	244
Rio Grande at Leasburg	16.2	8363500	Southern	Main	11	92	69	97	0	99
Rio Grande at El Paso, TX	17.1	8364000	Southern	Main	150	461	191	705	0	438
Rio Grande at Fort Quitman, TX	17.2	8370500	Southern	Main	96	136	32	161	0	0

Station Name	Air Temp	Water Temp	TDS	Fecal Coliform	Total Coliform	As	H_2S	Hg	Susp Sed
Rio Grande below Elephant Butte	98	306	244	29	0	14	0	14	29
Rio Grande at Leasburg	51	100	99	0	0	14	0	13	34
Rio Grande at El Paso, TX	223	620	440	114	7	96	0	60	189
Rio Grande at Fort Quitman, TX	99	140	97	100	40	62	0	23	0

3.1.2 Data Analysis

Data analysis focused on identification of statistical correlations among constituents and physical or chemical variables and the evaluation of seasonal and long-term trends in water quality. Data analysis was not completed for every gage and reach in the Rio Grande Basin. Instead, identified data gaps allowed the WQRT to focus on gages and reaches that had adequate data sets.

3.2 Gage Selection and Rationale

Data collected after 1975 and subjected to standard Quality Control practices were selected by the WQRT for further analysis. Two reservoirs (Abiquiu and Cochiti) and 18 USGS gaging stations (**Table M-3.4**) were selected for detailed analysis based on the availability of data at those sites and their respective locations within the basin. Generally, water temperature, dissolved oxygen, TDS/conductivity, and pH datasets were adequate for analysis. Arsenic, turbidity/suspended sediment, mercury, and hydrogen sulfide datasets were very limited, with small quantities of data present at a few gages. The remaining reservoirs and gage locations in the Basin were not selected for further evaluation because of the lack of suitable water quality data.

Table M-3.4. The Eighteen Gage Stations Used in the Water Quality Models

Reach ID	Station Name	Station ID	Section
01.4	Rio Grande near Lobatos, CO	8251500	Northern
03.3	Rio Grande below Taos Junction Bridge	8276500	Northern
06.2	Rio Chama above Abiquiu	8286500	Chama
07.2	Rio Chama below Abiquiu	8287000	Chama
07.3	Rio Chama near Chamita	8290000	Chama
09.0	Rio Grande at Otowi	8313000	Chama
10.2	Rio Grande at San Felipe	8319000	Central
11.3	Jemez River below Jemez Canyon Dam	8329000	Central
12.0.b	Rio Grande at Albuquerque	8330000	Central
13.0	Floodway near Bernardo	8332010	Central

Reach ID	Station Name	Station ID	Section
14.0	Conveyance at San Acacia	8354800	San Acacia
14.0	Floodway at San Acacia	8354900	San Acacia
14.0	Conveyance at San Marcial	8358300	San Acacia
14.0	Floodway at San Marcial	8358400	San Acacia
15.2	Rio Grande below Elephant Butte Dam	8361000	Southern
16.2	Rio Grande at Leasburg	8363500	Southern
17.1	Rio Grande at El Paso, TX	8364000	Southern
17.2	Rio Grande at Fort Quitman, TX	8370500	Southern

3.3 Current Surface Water Quality Conditions and Correlations

Water quality relationships in the Rio Grande Basin are complex. Correlations among constituents vary from gage to gage due to the numerous natural and anthropogenic influences affecting the watershed. To assess relationships of discharge and air temperature with other water quality constituents, pairwise Pearson's Correlations were run for every constituent (**Table M-3.5**). Constituent data were log-transformed as appropriate to determine best correlations. Modeled after Healy (RM-2 1997), for any relationship, if the Pearson's correlation coefficient is greater than or equal to 0.7, or less than or equal to –0.7, it is a strong correlation. If the correlation is between 0.3 and 0.7, or between –0.3 and –0.7 then it is a moderate correlation. If the correlation coefficient is between –0.3 and 0.3, then there is no correlation. Constituents with wide data ranges were natural log transformed to normalize the data. According to Ramsey and Schafer (RM-35), if the ratio between the largest and smallest measurements is greater than ten or if the data is not normally distributed (skewed right or left), log transformation is a good choice. Log transformed data can be analyzed the same as non-transformed, normally distributed data. Correlation analysis facilitated development of descriptive empirical models for analysis of potential alternative impacts and to identify potential multicollinearity in the modeled data. Only significant correlations and correlations important in the models are described below. For minor correlations, refer to **Table M-3.5**.

Table M-3.5. Correlations among All Evaluated Water Quality Constituents

	Discharge	log Discharge	Turbidity	log Turbidity	Dissolved Oxygen	pH	Hg concentration	Conductivity	log Conductivity	Air Temperature	Water Temperature	TDS	log TDS	Suspended Sediments	log Suspended Sediments	Fecal Coliform Counts	Coliform Counts
Discharge	1.000																
log Discharge	0.994	1.000															
Turbidity	0.114	0.945	1.000														
log Turbidity	0.308	0.725	0.975	1.000													
Dissolved Oxygen	-0.173	-0.297	-0.442	0.927	1.000												
PH	-0.141	-0.079	-0.027	0.107	0.939	1.000											
Hg concentration	0.064	0.057	0.023	-0.074	-0.792	0.904	1.000										

	Discharge	log Discharge	Turbidity	log Turbidity	Dissolved Oxygen	pH	Hg concentration	Conductivity	log Conductivity	Air Temperature	Water Temperature	TDS	log TDS	Suspended Sediments	log Suspended Sediments	Fecal Coliform Counts	Coliform Counts
Conductivity	-0.593	-0.087	-0.222	0.114	0.032	0.006	0.937	1.000									
log Conductivity	-0.647	-0.101	-0.221	0.139	0.067	-0.018	0.900	0.997	1.000								
Air Temperature	0.183	0.209	0.315	-0.589	-0.025	-0.003	-0.131	-0.162	0.930	1.000							
Water Temperature	0.123	0.193	0.343	-0.603	-0.019	-0.009	-0.122	-0.151	0.799	0.990	1.000						
TDS	-0.603	-0.115	-0.236	0.134	0.015	0.017	0.919	0.943	-0.061	-0.109	0.941	1.000					
log TDS	-0.652	-0.143	-0.241	0.165	0.051	-0.008	0.885	0.975	-0.101	-0.157	0.900	0.997	1.000				
Suspended Sediments	0.054	0.558	0.554	-0.168	-0.164	0.140	0.129	0.079	0.086	0.164	0.151	0.085	0.931	1.000			
log Suspended Sediments	0.293	0.497	0.645	-0.251	-0.209	0.136	-0.038	-0.106	0.102	0.264	-0.011	-0.100	0.652	0.971	1.000		
Fecal Coliform Counts	0.093	0.282	0.183	-0.212	-0.243	0.209	0.136	0.108	-0.047	0.128	0.116	0.063	0.401	0.367	0.942	1.000	
log Fecal Coliform Counts	0.209	0.302	0.336	-0.310	-0.319	0.220	0.044	0.012	0.020	0.215	0.037	-0.017	0.335	0.455	0.667	0.984	1.000

Water quality constituents in the Rio Grande change along the length of the river as well as seasonally and temporally. Both non-point and point source pollution affects water quality in the Rio Grande Basin. Non-point sources of runoff from the watershed include urban areas, forested areas, and agricultural areas. Point sources are directly input into a water body from a source such as a feedlot, wastewater treatment plant, or factory. Wastewater affluent inflows from larger municipalities such as Albuquerque, Rio Rancho, El Paso, and Las Cruces are significant, sometimes contributing large amounts of discharged material to the Rio Grande (RM-3 Moore and Anderholm 2002).

3.3.1 Air Temperature

Air temperature data acquired from NOAA Weather Services were used as a correlate for seasonal constituents such as water temperature and dissolved oxygen. The correlation analysis shows a strong correlation between air temperature and water temperature at most gages, and a strong to moderate correlation between air temperature and DO. At some gages, air temperature also showed some moderate correlations with pH, conductivity, fecal coliform, and total arsenic.

3.3.2 Water Temperature

Water temperature increases from north to south throughout the system (**Figure M-3.1**). The highest recorded temperatures occur during summer months and were measured at gages downstream of the Albuquerque gage. The lowest surface water temperatures were recorded in the Rio Grande headwaters and along the Rio Chama during winter months. However, all stations exhibited lower temperatures in winter months and increasing temperatures through the spring and summer. Higher air temperatures during summer months likely cause these changes.

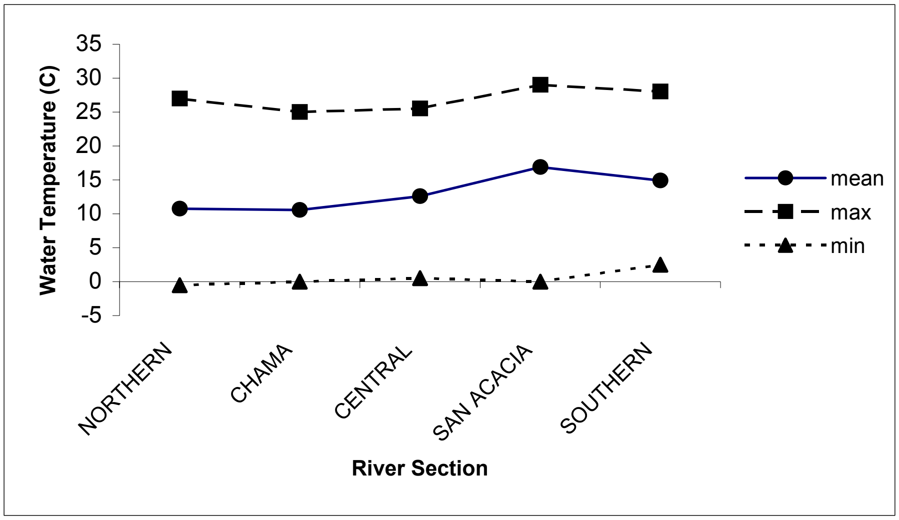

Figure M-3.1. Mean, minimum, and maximum water temperatures per river section.

Reservoirs may impact the water temperature in the Rio Grande. However, datasets from directly below the major Rio Grande dams are limited. Bottom-release dams discharge cold water from the hypolimnion into the stream surface water, thus causing stream water temperatures to be colder than normal. Small differences in maximum temperatures were observed below Elephant Butte Reservoir. Data from the gage below Elephant Butte indicated that maximum summer temperatures were approximately 8°C lower below the dam than in the reservoir inflow near San Marcial (28°C below Elephant Butte Dam versus 36°C at San Marcial). However, the average and minimum temperatures were not noticeably different below the dam. Available data showed no noticeable difference between water temperatures at inflows and outflows of Abiquiu and Cochiti dams. The gages above and below Abiquiu Dam had water temperature data only for limited periods and were not suitable for comparison purposes. Data from the gage below Cochiti Reservoir also were limited, and this gage also was not selected for the analysis.

Water temperature was generally lower with high discharges, usually in association with reservoir operations and/or runoff. High water temperature values were generally associated with low discharges and the high air temperatures that occur in summer months. Water temperature showed a strong to moderate negative correlation with DO at most gages. Some gages showed moderate correlations between water temperature and the natural log of discharge, concentration of suspended sediment, fecal coliform, and total arsenic.

3.3.3 Dissolved Oxygen

The concentration of dissolved oxygen in water is dependent on water temperature, salinity, and atmospheric pressure. Oxygen is incorporated into water, and dissolved oxygen levels are affected by three primary mechanisms: diffusion from surrounding air, oxygen production during photosynthesis, and aeration caused by natural and artificial turbulence processes. Dissolved oxygen is necessary for all forms of aquatic life in the Rio Grande Basin. Dissolved oxygen levels above 5.0 mg/L are optimal for the success of aquatic life forms. Values below 5.0 mg/L increase the stress on aquatic communities.

Available data were insufficient to establish baseline conditions for dissolved oxygen at the Rio Chama gages above and below Abiquiu Reservoir but were adequate for all other gages. The presence of dissolved oxygen varies greatly by season, with the lowest dissolved oxygen values being directly correlated with higher air and water temperatures. The lowest values were recorded during the warmest time of the year. The northernmost gages (those with lower water temperatures) had noticeably higher average levels of dissolved oxygen than gages in the southern reaches (higher water temperatures) (**Figure M-3.2**).

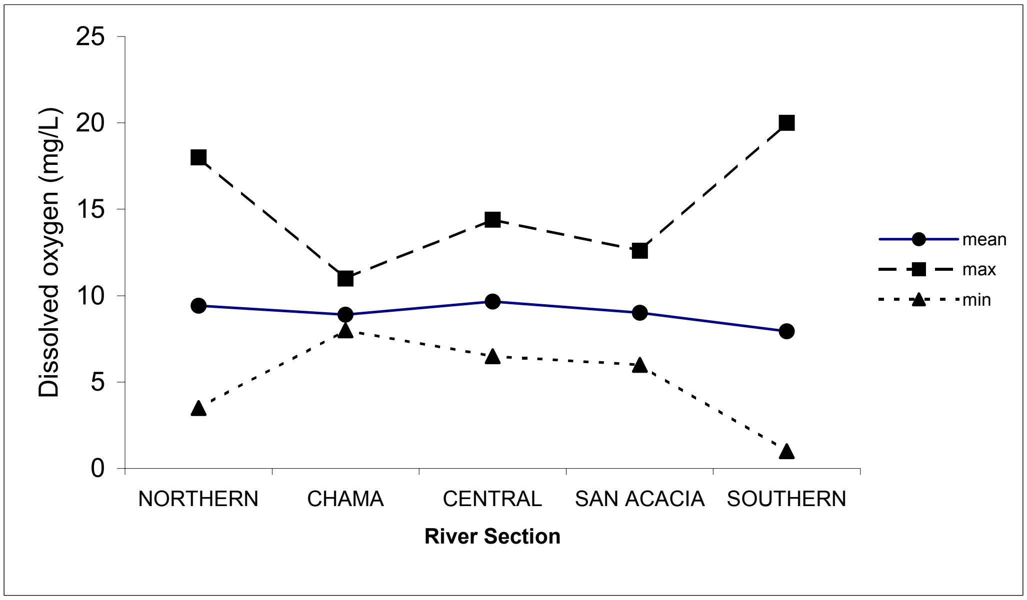

Figure M-3.2. Mean, minimum, and maximum dissolved oxygen values per river section.

Dissolved oxygen concentrations measured at the gage below Elephant Butte Dam were noticeably different from those observed at the other gage locations in the Rio Grande Basin. During winter months, the below Elephant Butte gage exhibited the highest average dissolved oxygen value in the Basin (11.71 mg/L), but had the lowest dissolved oxygen concentrations during summer and fall months. Average dissolved oxygen concentrations during summer months below Elephant Butte Reservoir were 3 mg/L less than those measured at the San Marcial gage near the reservoir inflow during the same time (3.9 mg/L below Elephant Butte versus 6.9 mg/L at San Marcial). No other gages had average dissolved oxygen concentrations below 7.2 mg/L during the same period.

Thermal stratification and oxygen limitations that have been observed in the Elephant Butte Reservoir hypolimnion are possible explanations for the substantially different dissolved oxygen readings. During the winter and at the beginning of the summer, the hypolimnion may contain more dissolved oxygen because colder water holds more oxygen than warmer water. During summer months, microorganisms break down organic materials in the hypolimnion, consuming dissolved oxygen. Continued microbial decomposition eventually results in an oxygen-deficient hypolimnion. If the lake is eutrophic, or nutrient rich, this process may be accelerated by increased microbial activity, and the dissolved oxygen in the lake could be depleted before the end of summer. This process and the release of the oxygen-depleted water may contribute to the low dissolved oxygen levels observed below Elephant Butte Dam. This same process may occur in Abiquiu Reservoir, where data collected by the U.S. Army Corps of Engineers indicate that a similar zone of oxygen-deprived water may occur during August and September at depths greater than 10 m. However, data were not available to assess whether water with low oxygen levels is discharged from the reservoir (RM-36 U.S. Army Corps of Engineers 2001).

The dissolved oxygen content of the Rio Grande correlates negatively with water temperature (lower temperature = higher DO). DO was also strongly to moderately correlated with air temperature, indicating that DO is affected by season. There were moderate correlations between DO and the concentration of suspended sediments and fecal coliform loads. At some gages, there were moderate correlations between DO and TDS and turbidity. Many of these constituents may not be directly affected by DO, but may simply respond to the same environmental correlates in the river system.

3.3.4 Total Dissolved Solids/Conductivity

Total dissolved solids (TDS) are the sum of the organic and inorganic materials dissolved in the water, and can be used as an indicator of water quality. TDS is composed of organic matter, salts, minerals, and metals originating from both natural and anthropogenic sources. Anthropogenic sources include faster evapo-transpiration rates caused by impoundments, leaching of agricultural chemicals, and wastewater effluent. Natural sources include mineral dissolution, precipitation, and evapo-transpiration (RM-3 Moore and Anderholm 2002).

Data from the gages above and below Abiquiu Dam were insufficient to establish baseline conditions for TDS. TDS were highest in the middle and lower reaches of the basin and lowest in the upper reaches (**Figure M-3.3**). Many of the northern gages, including the gages above Cochiti Dam in the Northern and Chama Sections and at San Felipe, Albuquerque, and Bernardo in the Central Section, had relatively low TDS (100-300 mg/L). At the Jemez River gage there was an influx of higher loads of total dissolved solids. However, the relatively low volume of water entering the mainstem Rio Grande at the Jemez River confluence did not noticeably increase TDS values downstream. Below the Albuquerque gage, TDS began to increase. There was a slight seasonal increase at Bernardo, then substantial increases at San Acacia and San Marcial, followed by a decrease as the river flowed through Elephant Butte Reservoir and Dam. The highest levels of TDS in the system were found downstream at the El Paso and Fort Quitman gages, where they were consistently high throughout each season. Fort Quitman TDS values were higher than the averages recorded at any other gage in the system. Throughout the system, the highest TDS values occurred during winter and summer/fall periods. Most of the gages in the system had their lowest average values during the period associated with snowmelt runoff.

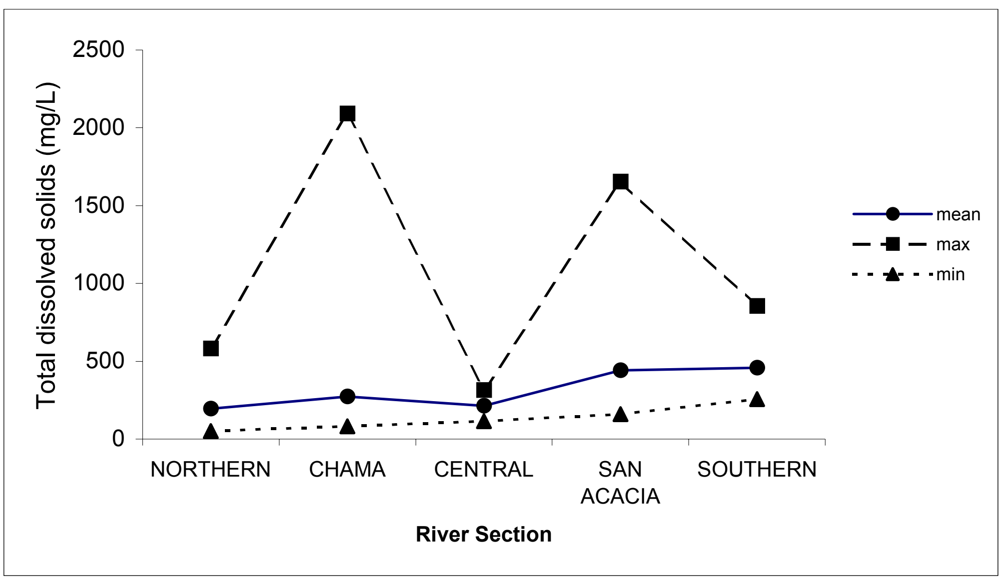

Figure M-3.3. Mean, minimum, and maximum total dissolved solids values per river section.

Conductivity is the measure of water's ionic content and hence its ability to conduct electricity. The higher the content of ionic material, the higher the conductivity of the water. Conductivity is directly related to water temperature. Specific conductivity can be a good measure of water salinity and total dissolved solids. Conductivity within the Rio Grande system varies with latitude and the inflow of major tributaries. In lower reaches of the Rio Grande system, adjacent land uses are likely causes of conductivity changes.

Total dissolved solids correlate strongly to moderately with discharge. The natural log values of both TDS and discharge generally had stronger correlations than the non-transformed values. TDS was also strongly correlated with conductivity at all gages. The strong correlation existed because TDS and conductivity measure basically the same parameter—dissolved solids in the water system. A few gages show moderate correlations between TDS, air temperature, and water temperature.

3.3.5 pH

Sufficient data existed to establish baseline conditions for pH at all selected locations except the gages above and below Abiquiu Reservoir. Average pH values remained relatively consistent between gages in the basin (**Figure M-3.4**). Average pH for all gages was 8.1 (minimum average = 8.0 at Conveyance Channel near San Acacia, maximum average = 8.3 at Leasburg).

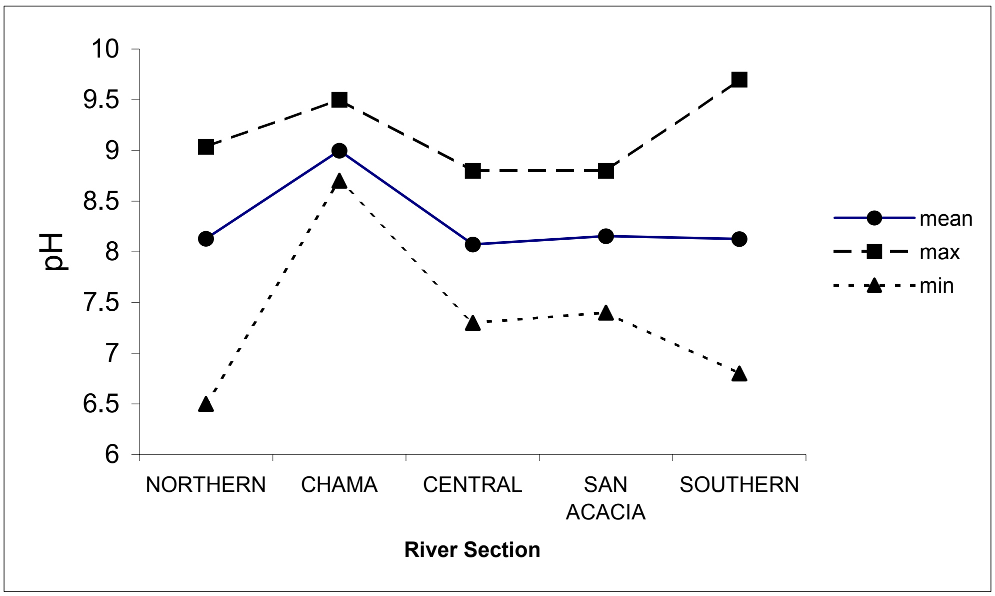

Figure M-3.4. Mean, minimum, and maximum pH values per river section.

Very few relationships were evident between pH and other water quality constituents. However, pH was strongly correlated with dissolved oxygen at the gage below Elephant Butte Dam (Pearson's correlation coefficient = 0.73). When dissolved oxygen decreased at the Elephant Butte gage, a corresponding decrease in pH (the water became more acidic) was evident. Passell et al. (RM-37 2004) found significant increases in pH at Albuquerque and downstream.

Correlations between pH and other constituents were weak. The pH values across all gages were between 7.0 and 9.0. Finding strong linear relationships with data in such a small range is difficult. However, at a few gages, the pH values had moderate correlations with discharge, concentration of suspended sediment, water temperature, TDS, and fecal coliform counts. The pH was back-transformed to the hydrogen ion concentration, but this did not improve the strength of any correlations or models.

3.3.6 Turbidity/Suspended Sediments

Water velocity largely determines the composition of the suspended load. Turbidity can greatly affect water quality and induce changes that may alter the composition of an aquatic community (RM-21 Wilber 1983). For example, higher turbidity (caused by a large volume of suspended sediment) may result in reduced light infiltration. At each selected gage there is variation within the system because of a series of factors, one being reservoir operations. The reservoirs have the ability to filter a portion of the sediment behind the dam, releasing far less than the amount that flows into the reservoir.

Turbidity varies by season and latitude throughout the Rio Grande system. The lowest turbidity values were between the months of November and February, with values increasing as the year progressed. Values were highest during the warmer months, when runoff from storm events rapidly increased river discharge and increased the load of suspended sediments and turbid waters. Turbidity and suspended sediment loads also increased downstream. Values were lowest in the Northern and Rio Chama sections and were highest in the San Acacia section, where the river was heavily influenced by inflows from the Rio Puerco and Rio Salado as well as other large tributaries upstream in the Albuquerque area (**Figure M-3.5).**

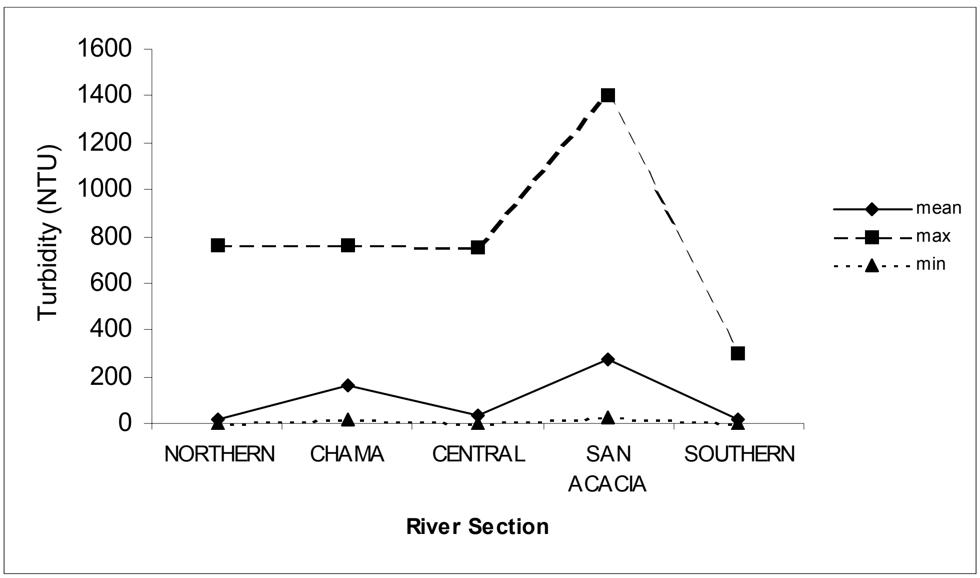

Figure M-3.5. Mean, minimum, and maximum turbidity values per river section. Units of measurement for turbidity in Nephelometric Turbidity Units (NTUs).

At the headwaters of the Rio Grande, suspended sediment decreased between gages, as groundwater and tributary inflows with low concentrations of suspended sediments dilute the Rio Grande and the landscape of the headwaters lacks erodable material. Suspended sediment concentrations increased downstream but were interrupted by reservoirs, where the particles settled out of the water column (RM-1 Levings et al. 1998) (**Figure M-3.6**). The Rio Salado and Rio Puerco contribute large quantities of sediment to the Rio Grande, and gages below these tributaries had high suspended sediment concentrations.

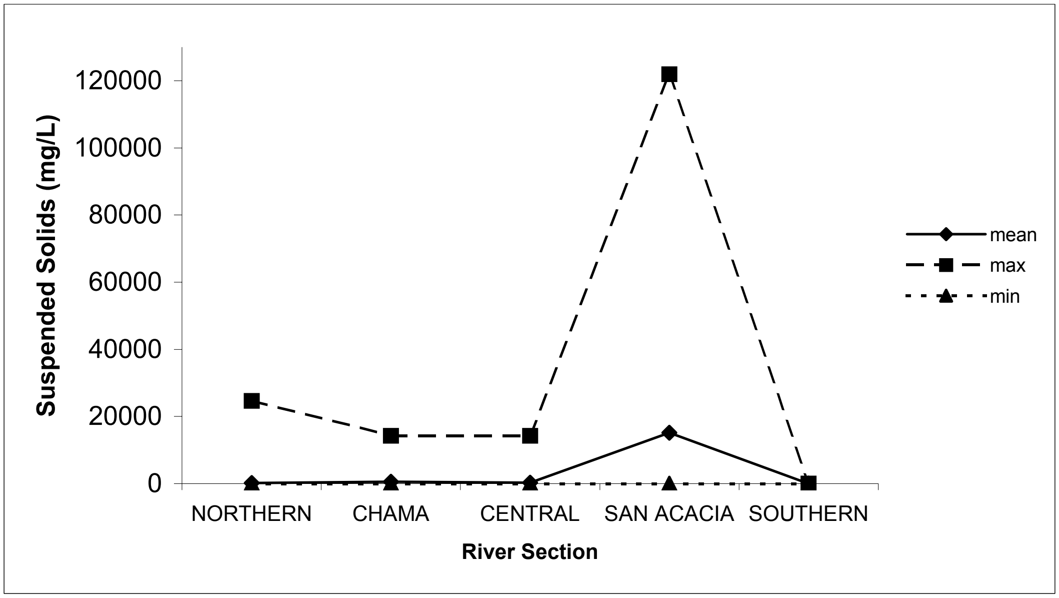

Figure M-3.6. Mean, minimum, and maximum suspended sediments values per river section.

Measurements of the amount of sediment being transported in the Rio Grande and its inflowing tributaries assisted in determining the amount of aggradation and degradation within the river. Areas of the San Marcial Reach have accumulated 25 feet of sediment over the last 100 years (RM-16 Wilson 1999). Seasonal inflows from the Rio Puerco and Rio Salado, ephemeral tributaries that carry large sediment loads, contributed much of the sediment. The Rio Puerco, the largest contributing watershed within the Rio Grande Basin (**Table M-3.6**), contributes 45 percent of the sediment to the river but only 3 percent of the runoff (RM-38 Hay 1972).

Table M-3.6. Major Contributing Tributary Watersheds in the Rio Grande Basin

Tributary	Section	Size (mi^2)
Rio Puerco	San Acacia	6,057
Rio Chama	Northern	3,159
Rio Salado	San Acacia	1,394
Jemez River	Central	1,038
Conejos River	Northern	821
Galisteo Creek	Central	670

Turbidity correlates strongly to moderately with the concentration of suspended sediments and moderately correlated with dissolved oxygen, air temperature, water temperature, and fecal coliform counts. The natural log of the concentration of suspended sediments correlates strongly to moderately with the natural log of turbidity. The correlation between these two constituents is similar to that between TDS and conductivity. Turbidity may be used to model the concentration of suspended sediments or vice versa. The natural log of suspended sediments concentration was also moderately correlated with the natural log of fecal coliform counts.

3.3.7 Fecal Coliform

Fecal coliform is found in intestinal tracts of warm-blooded animals, and its presence is an indicator of pathogens in the waterway. Data for fecal coliform loads were limited in most of the Rio Grande Basin. In addition, there is a recent movement to use *E. coli* as an indicator of bacterial contamination rather than the broader class of fecal coliforms. Fecal coliform loads follow the same general pattern shown in turbidity/suspended sediments (**Figure M-3.7**). In general, loads of fecal coliform were highest following natural inflows from summer storm events. These events mobilize fecal material from upland sources and transport the contaminating bacteria to the Rio Grande, where water temperatures are suitable for fecal coliform activity. During winter and spring runoff events, low water temperatures may limit some fecal activity. Reservoirs act as sinks for fecal loads in the Rio Grande Basin, and lower mean values for fecal coliform counts occur downstream of Cochiti and Elephant Butte Reservoirs. Contamination from fecal coliform adds surplus organic matter to the system, and bacterial respiration lowers the amount of oxygen present. The lower oxygen levels may endanger aquatic life and can lead to fish kills.

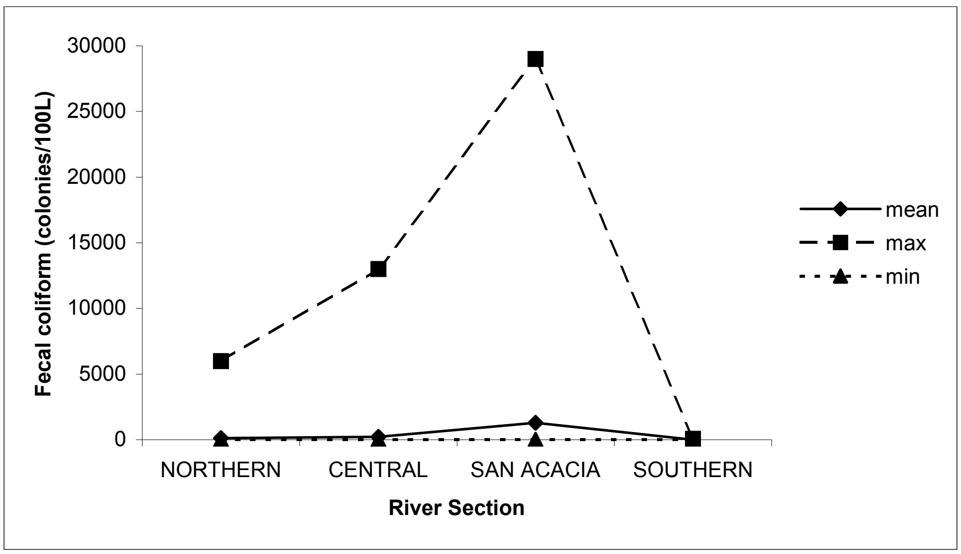

Figure M-3.7. Mean, minimum, and maximum fecal coliform values per river section.

Fecal coliform counts moderately correlated with turbidity, natural log of suspended sediments, and dissolved oxygen. Some gages had moderate correlations between fecal coliform, air temperature, and water temperature. High fecal coliform counts seem to occur with intermediate discharges. However, the correlation between fecal coliform and discharge was a challenge to model because high discharge dilutes fecal coliform counts. Several gages had little or no fecal coliform data, so modeling was further challenged.

3.3.8 Arsenic

Arsenic contamination usually occurs in groundwater rather than in surface water. However, arsenic can be found in surface water as a result of either natural or anthropogenic conditions. In the Rio Grande Basin, the geology of the Jemez Mountains and surrounding areas contributes natural arsenic loads to surface waters. Generally, arsenic is associated with volcanic rocks because these rocks are relatively high in arsenic, and because magmatic fluids also mobilize arsenic associated with silicic intrusions (RM-39 Chapin and Dunbar 1994). Anthropogenic activities such as mining and farming affect arsenic levels as well. Arsenic data were very limited in the dataset used for analysis. However, the data available suggest that arsenic loads remain consistent throughout the year, with little variation. Arsenic levels at the Jemez River gage (see **Table M-3.3c**) were high throughout the year and may contribute to increased arsenic loads downstream of the confluence of the Jemez and the Rio Grande. Arsenic levels were lower above the Jemez–Rio Grande confluence than at the Jemez River gage, and were higher below the confluence. Overall, arsenic is lower in the northern reaches and higher in the southern reaches.

Dissolved arsenic in the northern Rio Grande Basin was low (2 ppb on average), but increased downstream to the confluence of the Jemez River. Arsenic values were 28-66 ppb on average near the confluence (RM-39 Chapin and Dunbar 1994). Wilcox (RM-40 1997) found that dissolved arsenic concentrations were 2 mg/L at the San Felipe Gage, 14-20 mg/L in the Jemez River, and 11-20 mg/L at the Rio Rancho and Bernalillo Wastewater Treatment Plant (WWTP), and 4 mg/L at Los Lunas. Most rivers in the contiguous United States contain less than 1 ppb of arsenic (RM-41 Lettenmaier et al. 1991).

Arsenic can also be found in soils. According to Norman and Dilley (RM-42 2002), irrigated soils in the Rio Grande Valley are arsenic "time bombs," where concentrations in the San Acacia Reach decrease during the winter when irrigation is not occurring.

3.3.9 Mercury

Insufficient data were available to establish conditions for mercury in the surface waters of the Rio Grande Basin.

3.3.10 Nutrients

The largest concentrations of nutrients in the Rio Grande were either associated with suspended sediments or detected downstream of urban areas. Nutrients adsorb quickly to suspended sediments; thus, high nutrient concentrations were also associated with high levels of suspended sediments (RM-1 Levings et al. 1998). Elevated nutrient concentrations in urban areas were associated with wastewater treatment plants.

3.3.11 Nitrates

Nitrate (HNO_3) concentrations in the Rio Grande generally increased downstream. Headwater gages (e.g., Lobatos and Chama) had low nitrate concentrations (< 0.05 mg/L) because the area has little development and large surface water inflow. Sites downstream (e.g., Otowi) also had relatively low nitrate concentration (< 0.12 mg/L) due to dilution by groundwater and surface water (tributary) inflows. Two tributaries, the Conejos River and the Rio Chama, had low dissolved nitrate levels, and sites below their confluences with the Rio Grande had low nitrate concentrations due to dilution. Through agricultural land and the metropolitan area of Albuquerque, nitrate concentrations in the Rio Grande increased from 0.06 mg/L to 0.66 mg/L due to agricultural return flows and wastewater treatment plant effluent. Nitrate concentrations decreased downstream of Elephant Butte and Caballo Reservoirs due to settling and higher rates of nutrient uptake. Below Leasburg Dam and El Paso gages, nitrates increased again due to WWTP effluent.

Rio Grande nitrate concentrations vary seasonally, primarily because of snowmelt, which contains low levels of nitrates. On the other hand, the longer days and warmer temperatures associated with snowmelt in spring and summer increase nitrogen uptake.

3.3.12 Phosphorus

Total phosphorus concentrations also generally increased downstream due to groundwater and/or tributary inflow between sites, WWTP effluent, and agricultural return flows (via fertilizer application). Over half of the phosphorus measurements between 1992 and 1995 exceeded the recommended levels (RM-1 Levings et al. 1998). Tributaries contribute large amounts of sediment to the Rio Grande, and phosphorus adsorbs to suspended sediments; thus, larger phosphorus concentrations are recorded below the confluences with tributaries. Phosphorus settles in Elephant Butte and Caballo Reservoirs, but concentrations were high again below Leasburg and El Paso due to WWTP effluent and agricultural runoff.

3.3.13 Pesticides

Pesticides enter the Rio Grande system via application to urban lawns and agricultural fields. Pesticides were detected at 94% of all sites sampled, but levels were below EPA drinking water standards (RM-1 Levings et al. 1998). Please see Healy (1997) (RM-2) for a more detailed analysis of pesticides in the upper Rio Grande Basin.

3.3.14 *Salinity*

High salinity levels in the Rio Grande inhibit agricultural and municipal use. Return flows, predominantly agricultural, greatly increase the level of salinity in the river. Although fluvial increases in salinity can be both natural and anthropogenic, the major causes of increases in the Rio Grande are from changes in land use, diversions from rivers, and irrigation return flows. Walton and Ohlmacher (RM-15 1998) found that conductivity and chloride concentrations increased during the winter months and near El Paso when irrigation drains discharge more water to the river. Municipal use near El Paso increased salinity 200-300 mg/L as it transitions to treated wastewater (RM-43 Turner 1998).

3.4 Current Reservoir Water Quality Conditions

Most reservoirs are operated according to policies dictated by intrastate and interstate laws, decrees, and legal agreements. A variety of natural and anthropogenic factors should be considered in evaluating water management scenarios. For example, prolonged storage, reduced or increased reservoir flushing/discharge rates, low reservoir turnover rates, and greater reservoir depths can produce stagnation of the hypolimnetic waters of some reservoirs. Stagnation generally leads to oxygen depletion (especially where nutrient or dissolved organic inputs to the reservoir are high) and elevated concentrations of many dissolved metals and other contaminants. Operating reservoirs to reduce retention times and maintain lower water depths in summer and autumn can reduce such problems.

Managing water quality related to reservoirs requires consideration of both reservoir operations and influences from the surrounding watershed. The water quality environment affected by the alternatives considered under this EIS includes not only the waters in the reservoirs and their downstream discharges, but also all water from the Rio Grande watershed draining into the reservoirs. The three large dams that affect the mainstem of the Rio Grande are Cochiti, Elephant Butte, and Caballo. The Rio Chama, a major tributary of the Rio Grande, is impacted by Heron, El Vado, and Abiquiu reservoirs. Natural flow regimes, which normally peak during spring snowmelt and monsoon season, have been altered and are now in fact controlled by reservoir operations and diversions. Reservoir operations may be planned to mitigate against any negative effects, creating an environment with similar seasonal flows.

Changes in reservoir operations may have both negative and positive impacts. Water quality can be affected by changes in reservoir water level, the length of time the water is in the reservoir, and the size of releases from the dam and the season when they occur. Reservoirs can benefit downstream water quality by trapping sediment and potential pollutants, while worsening levels of other constituents such as dissolved oxygen. The effects reservoirs have on water quality are evident when comparing data from upstream and downstream (i.e., at USGS gages) of the impounded waters (RM-44 Anderholm et al. 1995). Reservoirs have a major influence on suspended sediment and turbidity levels in the Rio Grande Basin. There are noticeable differences in the values of these constituents downstream of Abiquiu, Cochiti, and Elephant Butte reservoirs, which sequester the turbid and suspended-sediment-rich waters, causing the suspended particles to settle to the reservoir bottom. Overall, the connectivity between upstream and downstream reaches is fragmented, affecting the transport of suspended matter and nutrients and thus water quality for aquatic communities (RM-45 Tracy and Thompson 2002).

3.4.1 General Conditions and Data Availability

No studies have researched extensively the effect reservoirs have on nutrients in the Rio Grande watershed. However, historical data show that nutrient concentrations decrease significantly in reservoirs due to nutrient uptake in these water bodies (RM-1 Levings et al. 1998, RM-3 Moore and Anderholm 2002). For this reason only Cochiti and Abiquiu Reservoirs were used in the analysis. Elephant Butte is included to reflect recent research concerning mercury and hydrogen sulfide within the reservoir. There is a continued need for additional research concerning water quality in and above and below Rio Grande Basin reservoirs.

3.4.2 Abiquiu Reservoir

Abiquiu Dam is in a 350-foot-deep canyon on the Rio Chama about 32 miles upstream from the confluence of the Chama and the Rio Grande. The reservoir's functions are flood control, water supply, flood retention, and recreation. The water is stored for agricultural, municipal, and industrial uses. Data analysis shows seasonal and temporal changes within the reservoir and upstream and downstream of the dam. The datasets used to analyze the changes were from the U.S. Army Corps of Engineers (USACE) (1978-1998) and from USGS gages. The gage data were instrumental in analyzing upstream and downstream change, allowing the WQRT to track constituents as they move through the reservoir. The USACE data, collected at various locations within the reservoir and at the outflow from the dam, were scattered, with monthly periods when data collection was continuous and breaks when collection was absent for years at a time. These data did, however, provide the WQRT with an understanding of how certain constituents change with reservoir depth.

Tables M-3.7a and M-3.7b summarize the completed analysis for Abiquiu Reservoir from the USGS gage data. For purposes of the analysis, changes upstream and downstream of the reservoir were compiled for three seasons of four months each: winter (November, December, January, February), spring (March, April, May, June), and summer (July, August, September, October). **Table M-3.7a** contains data for dissolved oxygen (DO), hardness (Hard), and pH. **Table M-3.7b** shows levels of fecal coliform (FC), conductivity (Cond), and temperature (Temp). Each table shows average values by season at inflow and outflow locations, change between inflow and outflow data (a negative value indicates the constituent value is higher at the gage above Abiquiu Reservoir), overall average of the constituent, high and low values recorded, and the range.

Table M-3.7a. Summary Analysis for Abiquiu Reservoir Using USGS Gage Data

Season	DO In	DO Out	DO Change	Hard In	Hard Out	Hard Change	pH In	pH Out	pH Change
Winter	10.30	10.70	0.40	260.42	221.00	-39.42	7.54	7.79	0.25
Spring	10.10	10.50	0.40	221.64	214.64	-7.00	7.79	7.76	-0.03
Summer	7.89	7.55	-0.34	183.06	189.59	6.53	7.82	7.65	-0.17
Overall	9.20	9.30	0.10	217.21	206.51	-10.70	7.74	7.72	-0.02
High	16.00	19.50		800.00	370.00		8.70	8.50	
Low	5.20	2.80		15.00	100.00		6.60	6.30	
Range	10.80	16.70		785.00	270.00		2.10	2.20	

Table M-3.7b. Summary Analysis for Abiquiu Reservoir Using USGS Gage Data

Season	FC In	FC Out	FC Change	Cond In	Cond Out	Cond Change	Temp In	Temp Out	Temp Change
Winter	45.65	43.53	-2.12	1.61	1.01	-0.60	5.43	5.96	0.53
Spring	29.86	30.41	0.55	1.12	1.29	0.17	10.87	9.12	-1.75
Summer	33.93	38.20	4.27	1.28	1.44	0.16	19.64	15.58	-4.06
Overall	35.01	36.50	1.49	1.28	1.29	0.01	13.18	11.03	-2.15
High	100.00	100.00		15.00	4.00		25.00	24.30	
Low	0.00	0.00		0.01	0.02		-3.00	-1.00	
Range	100.00	100.00		14.99	3.98		28.00	25.30	

At both inflow and outflow locations, dissolved oxygen was highest during winter months and decreased as air and surface water temperature warmed with the changing seasons (**Figure M-3.8**). However, the range between the highest and lowest recorded levels of DO is much higher at outflow (16.7 mg/L) than at inflow (10.8 mg/L). Thus, the natural inflow of dissolved oxygen from the Rio Chama does not vary as much as the regulated outflow from the reservoir. For the entire data set, however, there is virtually no difference in average annual dissolved oxygen values, with inflow at 9.2 mg/L and outflow at 9.3 mg/L.

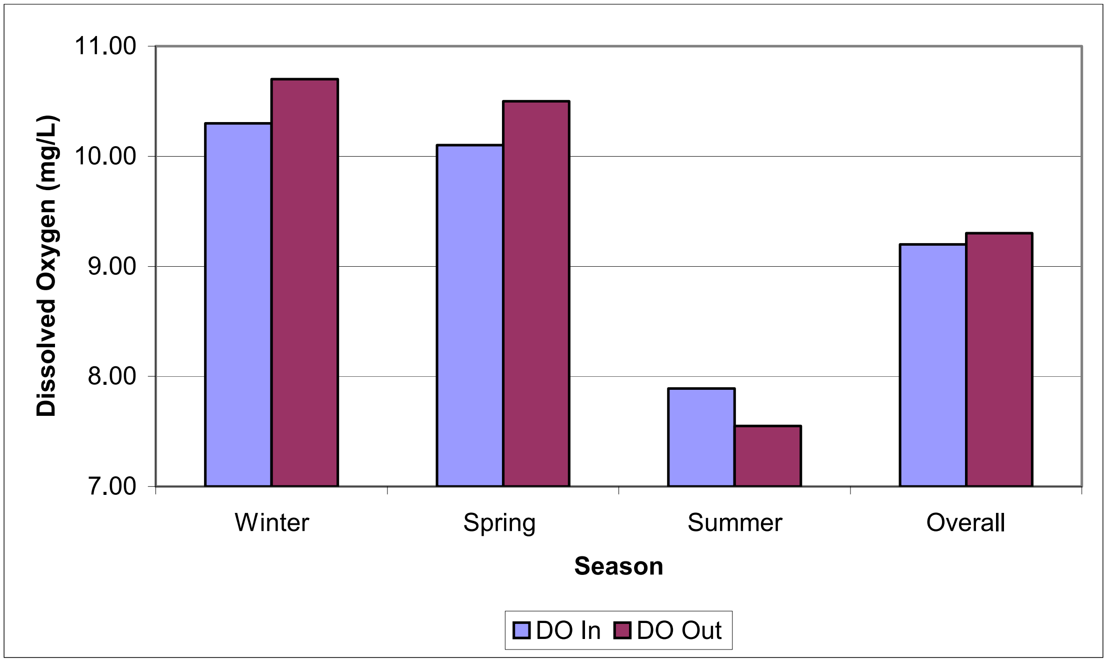

Figure M-3.8. Average dissolved oxygen at inflow and outflow locations by season for Abiquiu Reservoir.

Hardness values at inflow were highest during Winter and decreased during Spring and Summer (**Table M-3.7a; Figure M-3.9**). The pattern was similar at outflow. Although there is a slight variation in hardness between the inflow and outflow locations, annual averages for Abiquiu Reservoir are very similar. However, the range between the highest and lowest hardness values at inflow is 800 mg/L, while it is 370 mg/L at outflow.

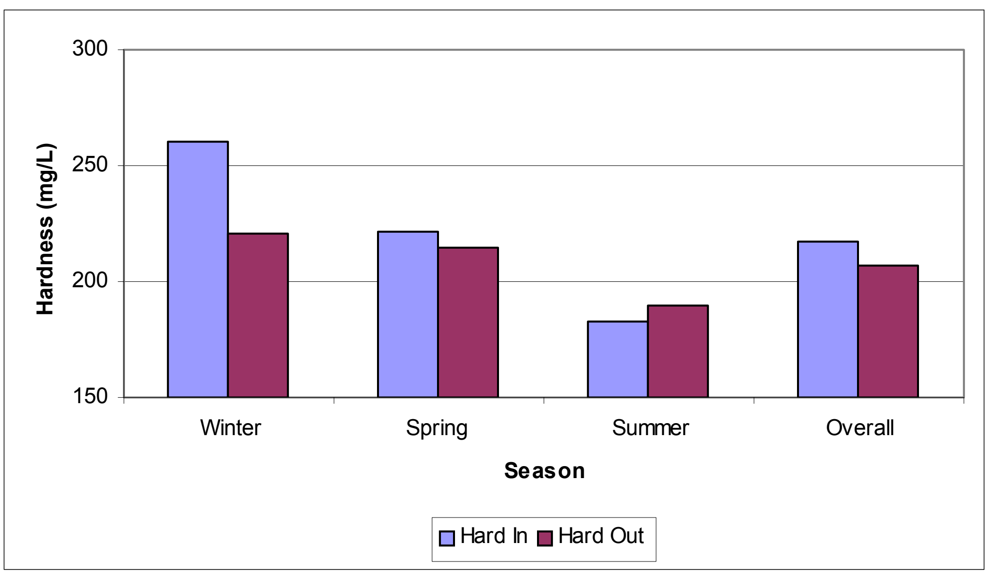

Figure M-3.9. Average hardness at inflow and outflow locations by season for Abiquiu Reservoir.

Average values for pH and fecal coliform are essentially the same for inflow and outflow locations, and the ranges are similar as well (**Figure M-3.10**). One noticeable difference in pH occurred between two time periods: 1975-1984 and 1985-1998. The average pH values during the 1975-1984 period were 7.22 at inflow and 7.46 at outflow, while average pH values during the 1985-1998 period were 8.21 at inflow and 8.18 at outflow. Fecal coliform concentrations were highest during winter for both inflow and outflow locations (**Figure M-3.11**).

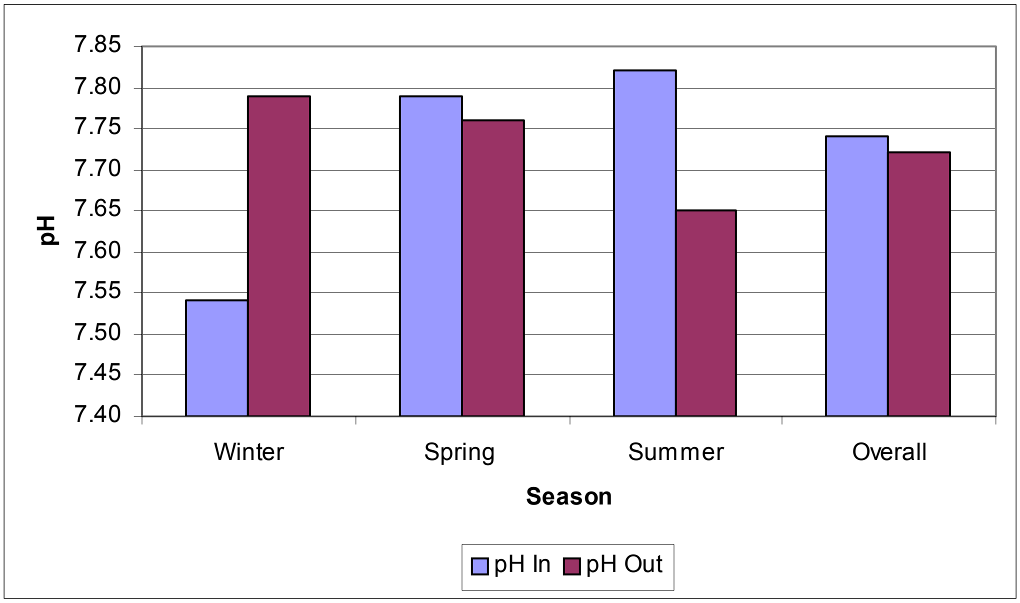

Figure M-3.10. Average pH at inflow and outflow locations by season for Abiquiu Reservoir.

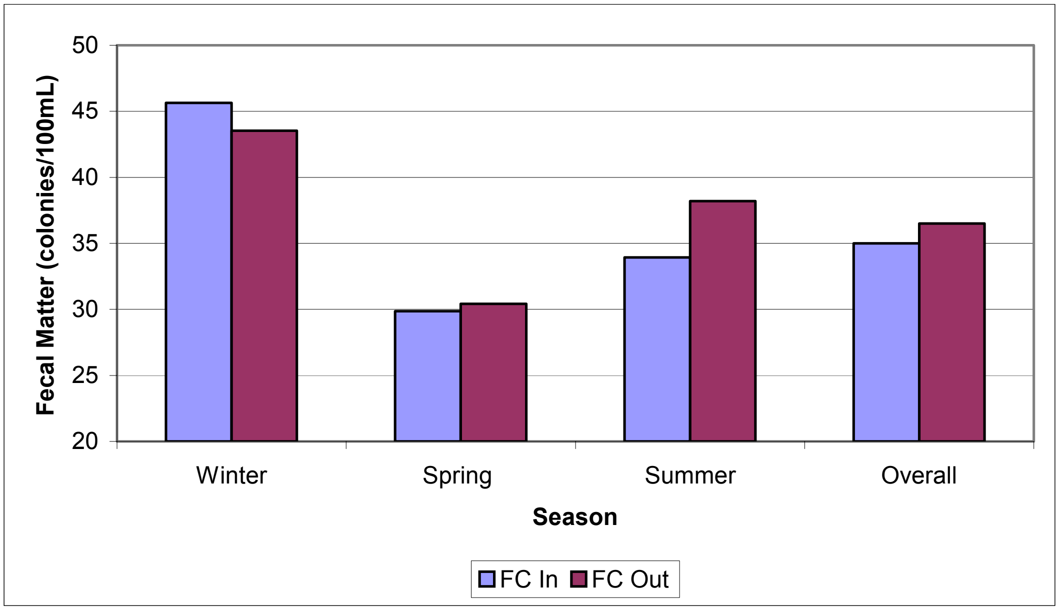

Figure M-3.11. Average fecal content at inflow and outflow locations by season for Abiquiu Reservoir.

In spring and summer, water temperature as expected was lower at outflow than at inflow (**Figures M-3.12 through M-3.14**). Temperatures were highest during summer, when there was a difference of 4.06º C between outflow and inflow. Temperatures at inflow and outflow were similar during winter, although slightly higher at outflow. Average temperatures for the year were higher at inflow than at outflow. Higher water temperatures during warmer months act synergistically with lower dissolved oxygen levels, creating adverse affects on organisms downstream (RM-36 Army Corps of Engineers 2001).

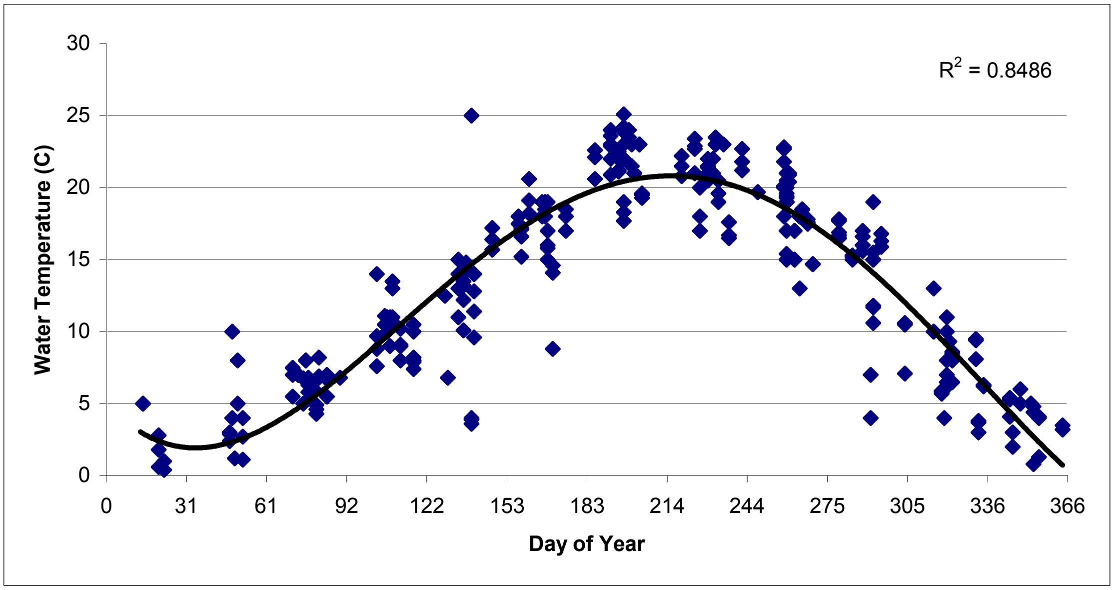

Figure M-3.12. Surface water temperature correlation plot for Abiquiu Reservoir.

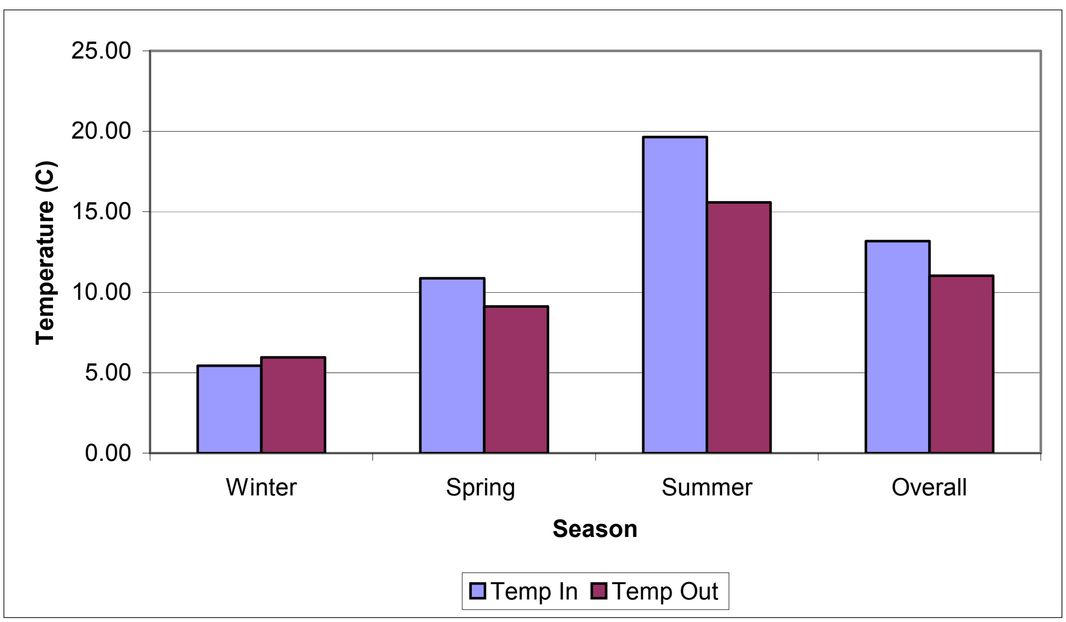

Figure M-3.13. Average surface water temperature at inflow and outflow locations by season for Abiquiu Reservoir.

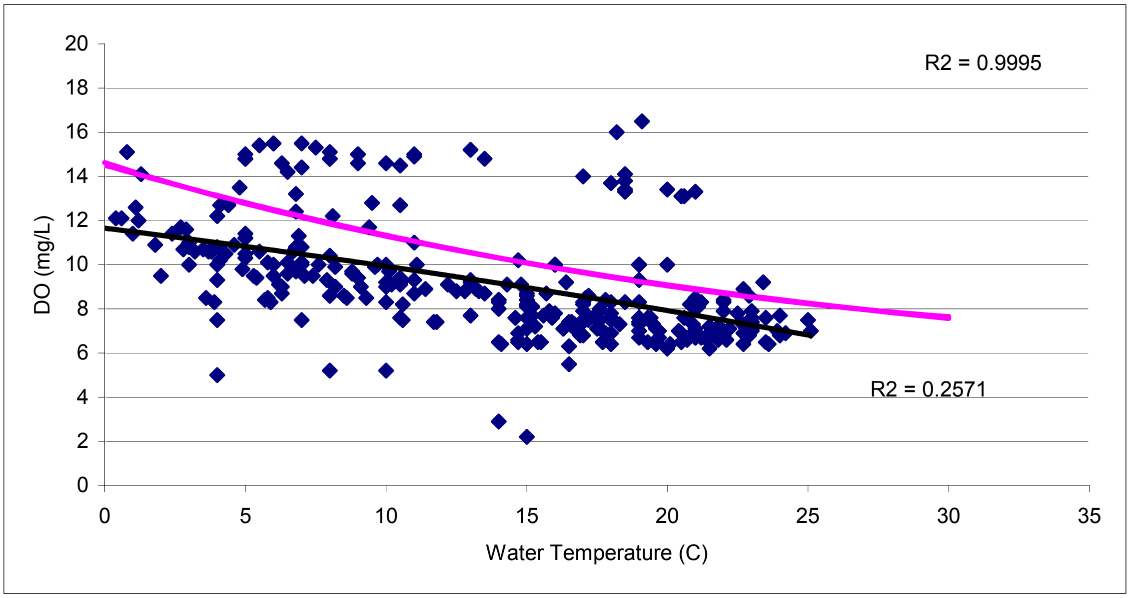

Figure M-3.14. Dissolved oxygen and surface water temperature correlation plot for Abiquiu Reservoir.

3.4.3 Cochiti Reservoir

Cochiti Reservoir was constructed in 1973 to serve as a flood and sediment control dam for the middle Rio Grande. A small recreational pool is maintained with San Juan–Chama water. Water quality studies that focus on Cochiti Reservoir are nonexistent. U.S. Army Corps of Engineers data for Cochiti Reservoir cover a short time period (1991-1999), at various locations on and immediately below the reservoir (**Table M-3.8**). Since USGS gage data are lacking immediately upstream and downstream of Cochiti Reservoir, the USACE data were used for this analysis. Los Alamos has recently completed analysis on plutonium within the reservoir, which has acted as a trap for materials coming from Los Alamos Canyon (RM-46 Rickman 1997), including plutonium 239 and 240. The Los Alamos study shows that while plutonium is attached to sediments at the bottom of the reservoir, no plutonium has leached into the reservoir water or fish. Cochiti Reservoir sediments are much thicker than those in Abiquiu and El Vado Reservoirs; Elephant Butte Reservoir sediment deposits are similar (RM-46 Rickman 1997).

Table M-3.8. Summary Analysis for Cochiti Reservoir Using U.S. Army Corps of Engineers Data

	DO In	DO Mid	DO Out	DO Change	pH In	pH Mid	pH Out	pH Change
Overall	7.24	7.50	9.55	2.41	8.09	8.15	8.00	-0.09
High	9.30	8.70	13.50		8.60	8.90	8.90	
Low	4.20	5.10	5.90		6.70	7.60	6.80	
Range	5.10	3.60	7.60		1.90	1.30	2.10	

Table M-3.8. Summary Analysis for Cochiti Reservoir Using U.S. Army Corps of Engineers Data

	FC In	FC Mid	FC Out	FC Change	Temp In	Temp Mid	Temp Out	Temp Change
Overall	28.75	0.57	5.63	-23.12	17.29	18.09	16.80	-0.49
High	100.00	2.00	25.00		25.30	25.70	28.00	
Low	1.00	0.00	0.00		3.10	5.00	5.00	
Range	99.00	2.00	25.00		22.20	20.70	23.00	

The USACE data for Cochiti Reservoir were recorded on the same day at three locations: inflow (In), middle of the reservoir (Mid), and immediately downstream of the reservoir (Out). Constituents measured were dissolved oxygen (DO), pH, fecal content (FC), and surface water temperature (Temp). The purpose of the analysis was to identify any spatial changes in constituents throughout the reservoir and any impact the reservoir may have on the constituents.

For dissolved oxygen and pH, all measurements were taken at the surface. Average dissolved oxygen (**Figure M-3.15**) changed dramatically between the inflow, middle, and outflow locations, rising 2.31 mg/L from inflow to outflow, demonstrating that dissolved oxygen levels rise as a result of the dam and reservoir. Values for pH did not differ significantly by location (**Figure M-3.16**). One noticeable difference was that the values were higher at Cochiti than at Abiquiu, although Abiquiu data recorded over the same temporal period were similar.

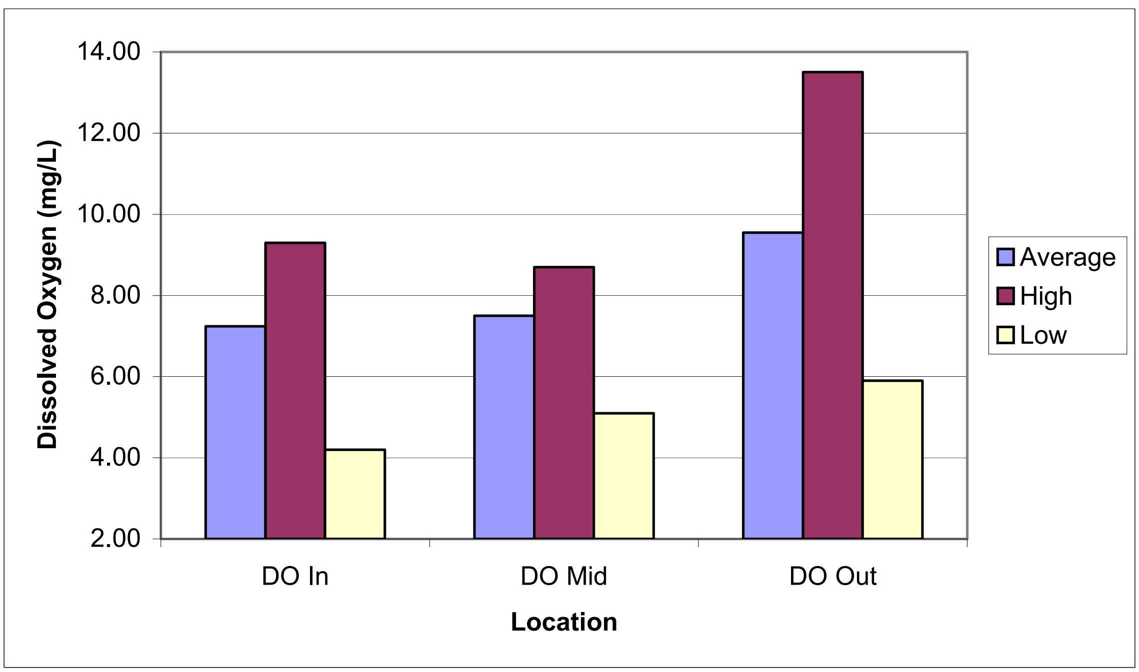

Figure M-3.15. Average dissolved oxygen by location for Cochiti Reservoir.

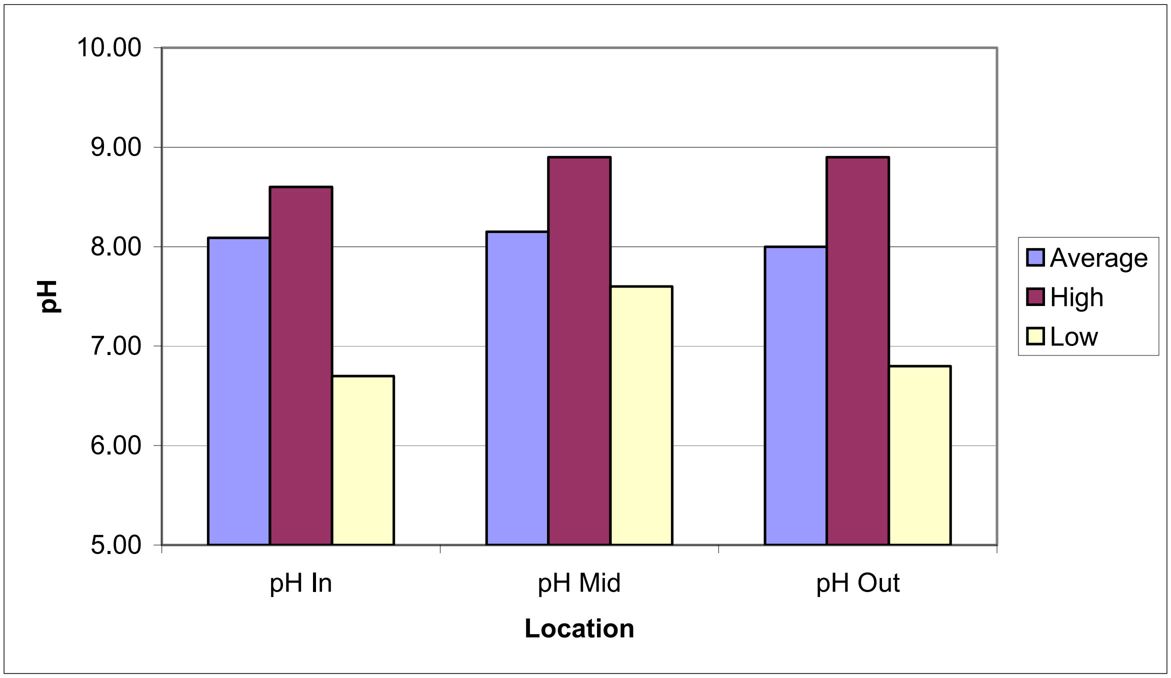

Figure M-3.16. Average pH by location for Cochiti Reservoir.

Fecal content varied by location (**Figure M-3.17**), although fecal values were not extremely high compared to values found in other reaches of the Rio Grande. Counts were much lower at outflow than at inflow, and almost nonexistent at the middle location. This distribution suggests that much of the fecal material present in a reservoir may be not be measurable at the surface because it has settled to the bottom. The higher values downstream of Cochiti Reservoir may be related to the bottom-releases associated with the dam. Surface water temperatures changed throughout the reservoir, with the highest values in the middle (**Figure M-3.18**) and the lowest at outflow. This pattern is similar to what is seen in most large bottom-releasing reservoirs. The inflow temperatures are colder than the middle temperatures because flowing Rio Grande water is contributing to the inflow area and coldest at outflow because the discharge comes from the hypolimnion.

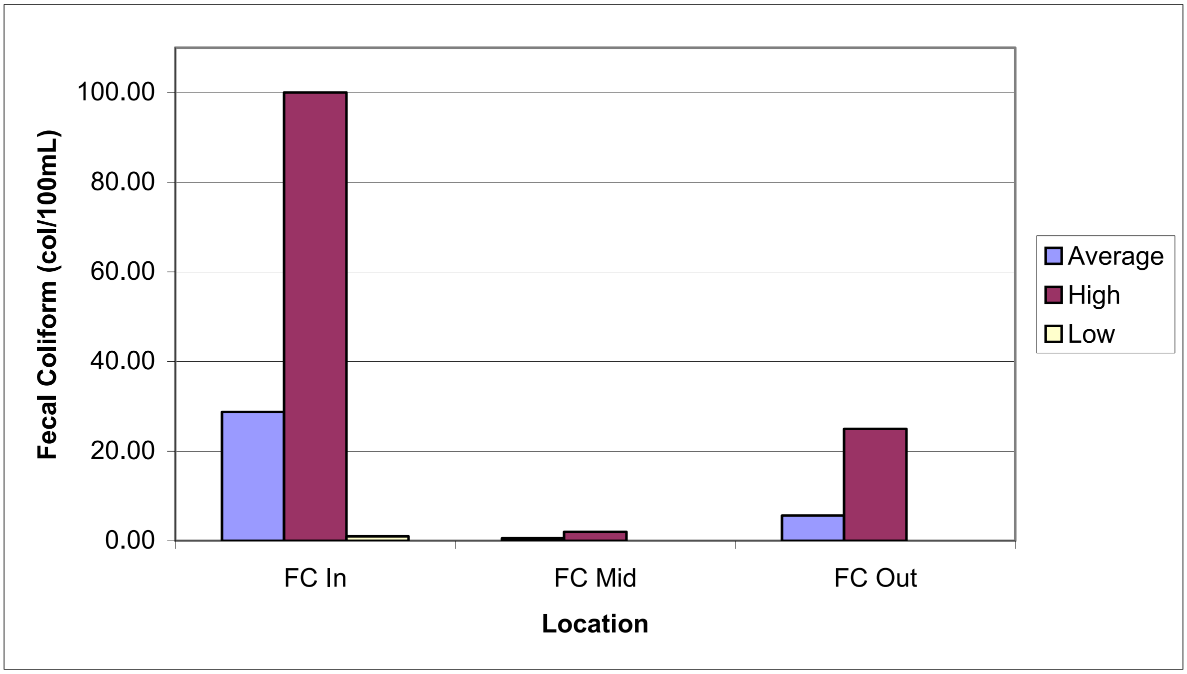

Figure M-3.17. Average fecal content by location for Cochiti Reservoir.

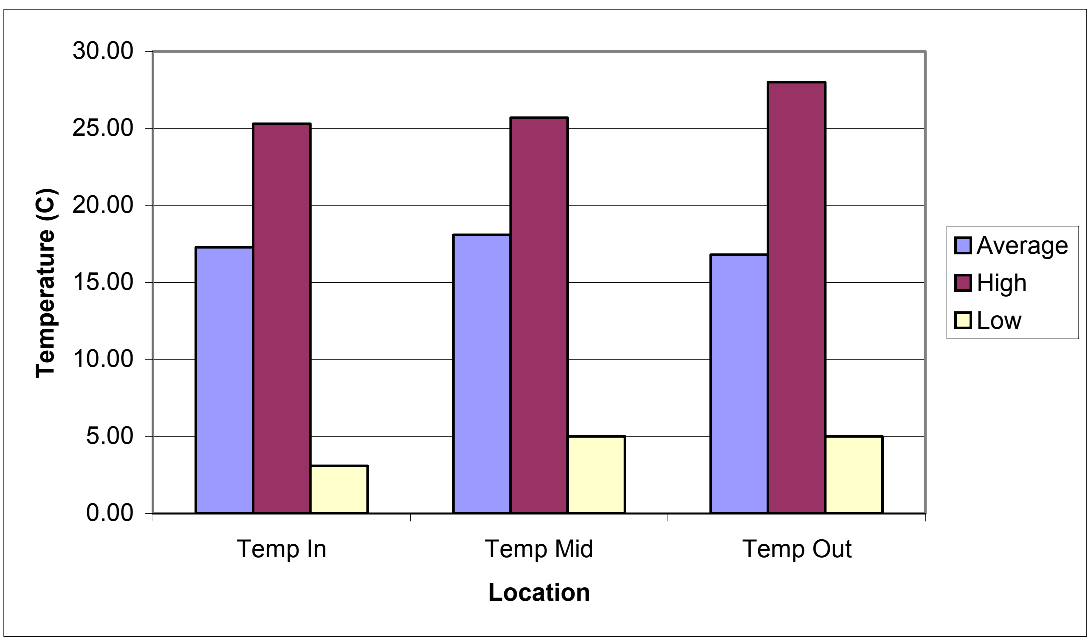

Figure M-3.18. Average surface water temperatures by location for Cochiti Reservoir.

3.4.4 Elephant Butte Reservoir

Very little data are available by which to accurately characterize water quality in Elephant Butte Reservoir. Comparing data collected at upstream and downstream USGS gages is nearly useless because of the distance between the San Marcial gage and the gage below Elephant Butte Dam. Government agencies or academic researchers through individual field efforts conducted to characterize a specific constituent collected the data used. Two constituents that have been recently researched at Elephant Butte Reservoir are hydrogen sulfide (H_2S) and mercury (Hg).

Very few data were available for hydrogen sulfide in the Rio Grande Basin. However, recent studies on Elephant Butte Reservoir indicate that hydrogen sulfide loads are problematic during summer months when the hypolimnion of the reservoir becomes anoxic. Conditions suitable for the generation of hydrogen sulfide may only occur when the reservoir is at relatively high storage levels and mixing does not occur in the lower levels of the water body. Releases of water with high levels of hydrogen sulfide may contribute to the lower pH levels observed below the dam when dissolved oxygen levels are low. When hydrogen sulfide comes in contact with oxygen in the outlet works of Elephant Butte, it may react with the oxygen and produce low levels of sulfuric acid, causing a decrease in pH. During stratification, hydrogen sulfide accumulates and persists until fall turnover. According to Canavan (RM-47 1999), at that time hydrogen sulfide is circulated into the epilimnion, oxidizes, and is precipitated out as sulfate (SO_4). Hydrogen sulfide in the hypolimnion does not pose a large problem for the reservoir because it remains isolated. The problem begins when water is released downstream, potentially impacting water and air quality. A survey of fish downstream of Elephant Butte Dam (reported by Jacquez in Canavan RM-47 1999) found almost no fish for 22 miles below the dam, to Caballo Reservoir. The source of the hydrogen sulfide in Elephant Butte Reservoir is not known; it may come from geothermal underground springs entering the hypolimnion or from internal microbial processes (RM-47 Canavan 1999).

Mercury and dissolved methylmercury (CH_3Hg^++) are water quality issues in this reach of the Rio Grande as well. Elephant Butte and Caballo Reservoirs are known to have high levels of mercury (RM-32 Johnson 1995). Johnson (RM-32 1995) considered potential sources of mercury in the reservoirs to be coal plants, atmospheric deposition, and mine wastes. Mercury is most likely transported to rivers by overland flow. Caldwell and Canavan (RM-48 1998) found that dissolved methylmercury increased in Elephant Butte Reservoir from July 1996 to October of 1996. During the same time period, concentrations in the reservoir were less than the detection limits. Canavan (RM-47 1999) also found that alkalinity, calcium (Ca), and hardness increase in depth following the start of stratification in Elephant Butte Reservoir.

3.5 Long-term and Seasonal Trends

An analysis of water quality based on seasonal flow was necessary to demonstrate the natural changes among constituents throughout the year. Knowledge of seasonal trends in water quality can aid in the interpretation of extremes and variations in the data. By organizing the data into three seasons (November through February, March through July, August through October), we were able to detect natural and anthropogenic changes spatially and temporally throughout the Rio Grande Basin. The grouping of the seasons was designed to capture periods of baseflow, runoff, and interflow.

The selected USGS gages and associated data were used for seasonal flow analysis. The data were imported into a geographic information system (GIS), and seasonal flow maps were generated in ESRI's ArcGIS environment. The classification system for the maps is based on the Jenks Natural Breaks method, which creates classes based on natural optimum breaks in the data. The following sections discuss seasonal trends by constituent and gage.

3.5.1 Temperature

Human activities do not substantially alter natural fluctuations in water temperature through the seasons. However, surface water temperatures measured directly downstream from dams are known to be lower than upstream values because of the effects of bottom-releasing dams. Depending on the location of the water being released from the reservoir, downstream temperatures may be extremely variable in comparison with upstream values (RM-18 USEPA 1987).

The highest temperatures, measured at gages downstream of Albuquerque (Central Section) and averaging over 20°C, occurred during Season 3 (summer). The lowest surface water temperatures were recorded in the Northern and Chama sections during Season 1 (winter). The above Abiquiu Reservoir gage on the Rio Chama recorded consistently low temperatures during each of the three seasons, with the lowest temperature values during Seasons 2 (spring) and 3. No substantial differences in temperature were noticed between the inflows and outflows at the gages near Abiquiu, Cochiti, and Elephant Butte Dams. However, these gages are not located directly above and below the dams, and it is therefore difficult to assess what impact the reservoirs have on water temperature within the Rio Grande system. Yet, at each location, the downstream gage had a higher surface water temperature, indicating that water temperatures in the Rio Grande Basin are influenced primarily by natural processes (e.g., latitude or air temperature).

3.5.2 Dissolved Oxygen

The available data indicated that levels of dissolved oxygen vary greatly by season throughout the Basin. Data from the above Abiquiu Reservoir gage during Season 1 and the below Abiquiu gage during Season 3 were insufficient for analysis; all other gages had adequate data.) The lowest dissolved oxygen values correlated directly with higher air and water temperatures and were recorded during the warmest time of the year, decreasing at each gage from Season 1 to Season 3. In addition, the Northern Section gages had noticeably higher dissolved oxygen levels than the gages in the San Acacia and Southern sections.

The data from the gage below Elephant Butte Dam did not fit the seasonal patterns observed at other gages. The Elephant Butte Dam gage had the highest dissolved oxygen level (11.71 mg/L) during Season 1 and the lowest during Seasons 2 and 3 (6.94 and 4.99 mg/L). Reservoir operations have a large impact on the fluctuation of dissolved oxygen within the system. Dissolved oxygen values at the nearest gage above Elephant Butte Dam (San Marcial) were very different than those recorded at the gage below the dam. Large variations were observed, especially as the seasons progressed and water and air temperatures increased. The extreme variations in dissolved oxygen caused by Elephant Butte Reservoir were not observed near Cochiti or Abiquiu Reservoirs. No other gage had average dissolved oxygen readings below 7.4 mg/L during any season.

3.5.3 Total Dissolved Solids

Total dissolved solids (TDS) are lowest in the upper reaches of the Rio Grande Basin and highest in the middle and lower reaches. The Northern and Chama section gages have relatively low TDS (100.01-300.00 mg/L) and have consistent values throughout each of the seasons. There are insufficient data for all seasons for the gages above and below Abiquiu Reservoir and for the floodway at San Acacia during Season 3. There is an influx of TDS at the Jemez River gage during each season, yielding higher TDS values there than at the gages above and below the confluence of the Jemez River and the Rio Grande during each flow season. The Jemez contributes large quantities of dissolved solids to the Rio Grande, as indicated by the high values measured at the gages. Below the Albuquerque gage, where the TDS levels are between 100 and 300 mg/L during each flow season, TDS increases. There is a slight seasonal increase at the Bernardo gage during all seasons, but considerable increases are measured at San Acacia and San Marcial, especially during Season 3. TDS decreases again as the river flows through Elephant Butte Reservoir (gages above and below Caballo Dam have high TDS values during each flow season), indicating that Elephant Butte Dam lowers the amount of TDS in the system. This is not a drastic seasonal decrease, but it is a noticeable one.

The highest TDS values in the Rio Grande Basin are found at the El Paso and Fort Quitman gages. Readings at these gages are consistently high throughout each of the flow seasons, with Fort Quitman showing higher averages than any other gages in the system. Thus, a large amount of total dissolved solids is being added to the system downstream from Leasburg Diversion Dam and the City of El Paso. The highest TDS readings throughout the system are measured during Seasons 1 and 3, while the lowest are measured at most gages during Season 2 (higher flows assist in reducing TDS). Cochiti Dam did not affect TDS levels. No conclusions were drawn from TDS levels associated with Abiquiu Dam, as the data were insufficient for analysis. Settling in Elephant Butte Reservoir causes a significant decrease in TDS. In general, a large dam like Elephant Butte has a significant impact on TDS, while dams of smaller magnitude such as Cochiti may have no impact or a small one.

3.5.4 pH

A pH range of 6.0 to 9.0 is ideal for invertebrates and freshwater fish. Above and below this range, there may be adverse affects. Data at the above Abiquiu Reservoir gage during Season 1 and the below Abiquiu Reservoir gage during Season 3 were insufficient for analysis. At all other gages, pH values were between 7.88 and 9.00 during each of the three flow seasons, with latitudinal and seasonal variability. Seasonal trends include a decrease in pH values from Season 1 to Season 2, a decrease or similar values in lower reaches from Season 2 to Season 3, and an increase or similar values in the upper reaches from Season 2 to Season 3. The highest pH values were recorded on the Rio Chama at the above Abiquiu Reservoir gage in Seasons 2 and 3.

3.5.5 Turbidity

Data were insufficient at the above Abiquiu Reservoir gage and the Jemez River below Jemez Canyon Dam gage during each season, and at the Leasburg Dam gage during Seasons 2 and 3. Turbidity varies by season and latitude throughout the system. The lowest turbidity values are recorded during Season 1, and the highest values occur during the warmer summer months. Turbidity increases down the length of the Rio Grande from the Northern Section to the inflow at Elephant Butte Reservoir, where the dam alters turbidity downstream. Turbidity is highest in the San Acacia Section of the Rio Grande study area. The Rio Puerco drains the largest area (6,057 mi^2) within the Upper Rio Grande and contributes large amounts of sediment during precipitation events and snowmelt. The Rio Salado, which drains an area of 1,394 square miles, also contributes large amounts of sediment to the Rio Grande system. Turbidity below Elephant Butte Dam is relatively low during each season, while values above the dam are much higher. Turbidity is again high downstream of the Leasburg Diversion Dam, especially from El Paso to Fort Quitman, during seasons 2 and 3.

The Rio Grande above the Otowi gage is a gaining stream with consistent flows. Downstream of the Otowi gage, the Rio Grande is a losing stream. Below the City of Albuquerque the majority of inflow to the Rio Grande is supplied by seasonal ephemeral flows. During large precipitation events, large quantities of sediment are transported to the river at high velocities. Therefore, turbidity is higher in the middle reaches during the rainy season and periods of snowmelt. The turbidity levels below Elephant Butte Dam are consistent low throughout the year, indicating that reservoir operations there lower turbidity levels. However, variations in turbidity values are not seen near Abiquiu Reservoir or Cochiti Reservoir.

3.5.6 Suspended Sediments

There are insufficient data from the Fort Quitman gage during each flow season. All other gages have sufficient data for each season. Suspended sediment load in the Rio Grande depends on the seasonality of flow and is positively correlated with stream flow. Thus, during seasonally high flows, from snowmelt and the rainy season for example, sediment values are higher. The middle reaches of the system have the highest average values of suspended sediments, with the two San Marcial gages (floodway and conveyance) having the highest values. These values are recorded during Season 3, although increases in suspended sediments are seen at other gages throughout the year. The high suspended sediment values likely result from storm events and sediment discharged into the Rio Grande via the Rio Puerco and Rio Salado. The lowest values are found at the Lobatos gage (Northern Section) and the gage below Elephant Butte Dam. The Lobatos gage receives very little sediment input, and suspended particles settle in Elephant Butte Reservoir, dramatically decreasing suspended sediments below Elephant Butte Dam in comparison to the values at the San Marcial gages above the reservoir.

Overall, suspended sediments increase from north to south in the Rio Grande Basin to Cochiti Dam. At that point, settling in Cochiti Reservoir causes a decrease in suspended sediments. Suspended sediment values then increase from below the confluence with the Jemez River to Elephant Butte Reservoir. After the immediate decrease below Elephant Butte Dam, suspended sediments increase again downstream. There is no noticeable change in suspended sediments above and below Abiquiu Reservoir.

3.5.7 Specific Conductivity

Data from the Fort Quitman gage are insufficient during each flow season; all other gages have sufficient data for each season to assess seasonal fluxes in conductivity. Low conductivity values (less than 600 µs/cm) were found at each gage above Cochiti Dam during all three seasons, with the lowest values being recorded at the Taos Junction gage (Northern Section). Higher conductivity values were found in the middle to lower reaches of the Rio Grande Basin, including along the Jemez River above the confluence with the Rio Grande and downstream of the confluences with the Rio Salado and Rio Puerco. The Jemez River gage has higher values than surrounding gages during each season, reaching average conductivity values of 1,534.81µs/cm during Season 1. The Jemez River drains a basaltic landscape, which is high in mineral content. Thus, the Jemez River appears to be a large contributor of minerals and ionic compounds to the Rio Grande Basin. However, the gages downstream of the Jemez River confluence do not have high conductivity readings.

The gages along the Chama Section show consistently low conductivity readings throughout each season, with very little seasonal change. Outside of the Jemez River gage, the Southern Section has the highest conductivity values. In addition, the reservoirs appear to have no impact on conductivity. There is no noticeable difference in conductivity upstream and downstream of the three major reservoirs in any of the seasons.

3.5.8 Fecal Coliform

Seasonality largely determines fecal content in surface water. Fecal coliform levels increase at higher temperatures, and fecal material is more likely to run off surfaces during the rainy season. Agricultural practices, including the application of fertilizer containing feces and livestock waste, also contribute to fecal contamination. High temperatures, runoff, and agricultural applications occur during Seasons 2 and 3, and the highest fecal coliform counts thus occur during spring and summer.

Data for fecal coliform within the Rio Grande Basin are sporadic, but the available data allow an interpretation of local variances in fecal coliform counts. Data are insufficient at the following locations: above Abiquiu and below Abiquiu (all seasons); Jemez River, Bernardo, and Leasburg Dam gages (all seasons); and the Albuquerque gage during Season 1. Fecal coliform counts are highest in the middle and lower reaches of the system. The Lobatos and Taos Junction gages (Northern Section) have relatively low fecal coliform counts through each of the flow seasons (0.01 to 400.00 col/100 mL of water). The area surrounding these gages is relatively undeveloped, and agricultural activity is low. Fecal counts increase significantly at the Otowi gage, decrease at the San Felipe and Albuquerque gages, then increase again at the San Acacia gages. The confluence with the Rio Puerco may cause the increase in fecal counts noticed at San Acacia. At the San Acacia and San Marcial gages, fecal content, on average, is above 200 colonies during each flow season and is consistently above 1,000 colonies. Two of the highest measured averages (above 3,500 colonies) occur at the floodway at San Acacia (4,117.25 colonies) and the floodway at San Marcial (3,573.00 colonies) during Season 3. At the Elephant Butte gage, fecal content is again low (less than 50 colonies during each flow season), indicating that the dam causes fecal matter to settle in the reservoir. Downstream of Elephant Butte and Caballo dams fecal matter is again high. At the El Paso and Fort Quitman gages, fecal content is consistently around 1,000 colonies during each of the three flow seasons, which may be directly correlated with wastewater inflows.

Overall, fecal coliform counts along the Rio Grande are relatively low to the Otowi gage, where there is a sharp increase; decreases to Albuquerque before increasing dramatically at San Acacia and San Marcial; and decreases abruptly below Elephant Butte Dam Fecal coliform is highest during Season 3 and lowest between Seasons 1 and 2. Although fecal matter content is lower below than above Cochiti Dam, it is most likely not a good indicator of how the dam affects fecal content within the system (fecal content is higher below the dam during Season 3). The distance between the gages is too great to make an accurate assessment. There is a sharp decrease in the average amount of fecal matter at the gage below Elephant Butte Dam in comparison to the average amount of fecal matter in the gages above the dam.

3.5.9 Other Constituents

Because of the number of gages with insufficient data, levels of arsenic, mercury, and carbon dioxide were not mapped by seasonal flow. However, some variation between gages was noted.

3.5.9.1 Arsenic

Data from the gages above Abiquiu Reservoir, below Abiquiu Reservoir, at Leasburg Dam during Season 2, and at Fort Quitman were insufficient for analysis. Overall, arsenic levels remain consistent throughout the year with little variation. Levels at the Jemez River gage are high throughout the year, indicating that the Jemez adds a noticeable amount of arsenic to the system from the basaltic terrain in this drainage. Arsenic levels above the Jemez–Rio Grande confluence are lower than at the Jemez River gage and below the confluence they are higher. There are no noticeable differences in connection with the dams and reservoirs, and seasonal trends are not easily identified. Overall, arsenic levels are lower in the upper reaches of the Rio Grande and higher in the lower reaches, which may be due to more agricultural activity in the south.

3.5.9.2 Mercury

Data are insufficient at the gages above Abiquiu Reservoir, below Abiquiu Reservoir, on the Jemez River, on the Rio Grande at Albuquerque (Season 3), at Leasburg Dam (Seasons 1 and 3), and at Fort Quitman. The only areas with sufficient data are in the middle and upper reaches of the system, with the highest values recorded between Otowi and San Marcial. Levels of mercury are high (0.21-0.40 μg/L) at Otowi throughout the year and are highest at San Marcial during Season 3. Mercury values below dams are lower than above dams. Although data are lacking near Abiquiu Dam, values are higher above Cochiti and Elephant Butte dams and lower below the dams during each flow season. These data indicate that the dams play a key role in mitigating the amount of mercury in the system. There is no direct seasonal association, but the highest values are measured during Seasons 2 and 3.

3.5.9.3 Carbon Dioxide

Data on carbon dioxide are insufficient from the gage above Abiquiu Reservoir. It is difficult to distinguish trends among the rest of the gages. Similarities can be discerned between the gages on the Rio Grande near Lobatos, below Taos Junction Bridge, and on the Rio Chama near Chamita. Carbon dioxide levels are 1-2 mg/L during Seasons 2 and 3 but vary during Season 1; they are highest for many gages during Season 1 and then decrease to Season 3. The gages on the Rio Grande at Otowi Bridge and San Felipe and on the Jemez River record 1-3 mg/L during each flow season. Readings from the gage below Elephant Butte Dam vary greatly throughout the flow season, with the highest (6.52 mg/L) recorded during Season 3. At Fort Quitman carbon dioxide levels fluctuate between 3 and 13 mg/L, with the highest average value during Season 3.

Seasonal changes in carbon dioxide levels are difficult to distinguish. Higher values tend to occur during Season 1 and Season 3, and lowest values typically are in Season 2. Average carbon dioxide levels vary below the dams, with readings <1 below Abiquiu Dam, increasing slightly below Cochiti Dam, and varying between 1.41 and 6.52 mg/L below Elephant Butte Dam.

4.0 Development of Upper Rio Grande Basin surface water quality models

4.1 Introduction

In river systems, including the Rio Grande, the boundary conditions that govern water quality include both environmental and anthropogenic factors. For example, environmental factors such as climate, air quality, geology, and biology can affect the water quality in a river system. Anthropogenic factors such as point source and non-point source inputs of pollution also influence the water quality of a system. To explain the observed variation, numerical models can be used to simulate natural conditions and to predict how water quality variables in a given system will respond to changes in boundary conditions.

Spatial variability of water quality is an important consideration for numeric models. Throughout a given river system, a change in location may result in a change in boundary conditions. For example, location within a river system can determine the amount of water entering the stream channel. The amount of water entering a stream from direct runoff in response to a precipitation event or by ground water inflow, determines the water budget of the system, and in turn affects the quality of surface water. Differences in physical basin characteristics such as the angle of the channel slope or the thickness or composition of surrounding bedrock or surficial deposits can cause a change in erosion-sediment yield. As a result, different locations within the Project Area can have environmental characteristics that may affect surface water quality differently from one location to the next.

Dam releases and water storage can influence water quality in a system, regardless of whether climate, air quality, geology, and biology are held constant. Dams within the Project Area, which are used to control the release and storage of surface water within the system, add to the inherent stream discharge variability. The annual average of mean daily discharge at locations throughout the project area illustrates the spatial variability of stream discharge. At a given stream gage, mean annual stream flow can vary from year to year, which could affect water quality variables. Short-term and seasonal variations of water quality resulting from changes in boundary conditions also affect water quality.

To estimate the response of selected water quality variables to spatial and temporal changes in environmental conditions, numeric, models were developed at locations distributed throughout the project area (Map M-1). To develop these models, historic data from 1975 to 2001 were loaded to a project database from federal and state water quality and climate data sources. Data in the project database provided an efficient and accessible method for storing, filtering, and analyzing water quality data.

4.2 Water Quality Database Development

Historical surface water quality and stream discharge data were collected from stream gages within the project area, including tributary streams. Data were obtained from the U.S. Geological Survey (USGS), State of New Mexico, U.S. Environmental Protection Agency (EPA), and U.S. International Boundary Water Commission (IBWC). Climate data including daily air temperature and precipitation records were obtained from National Oceanographic and Atmospheric Administration (NOAA) sources. Data were obtained for the main stem channel and tributary streams from the headwaters of the Rio Grande in south-central Colorado to Fort Quitman, Texas. Time-series data was variable for each study location, and ranged from January 1, 1975 to September 30, 2001. The database contains information for more than 1,500 water quality collection locations in the project area. Over 38,000 records of water quality data are stored in the database for over 80 physical and chemical water quality variables. In addition, 797,756 mean daily stream discharge data were loaded for selected gages throughout the project area.

4.2.1 *Database Tables*

Data loaded from federal and state systems were stored in tables containing individual records for each sampling date within the 1975 to 2001 time series. To ensure that data were organized appropriately, the database was designed to store data in tables that are normalized at a reasonable level. For this project, we use the term “normalize” to refer to the elimination of redundant or repetitive data. In addition, the term applies to the organization of related data stored in separate tables that can be tied together with other data sets by a logical matching field or characteristic. For example, water quality and stream discharge data are stored in separate tables. Each dataset is, in turn, related by the date and location where the measurements were collected. By relating each table to one another by date and location, the database is able to organize data in separate tables, while enabling information from these tables to be compared with one another.

4.2.2 Database Queries

The second stage of development was to create a series of queries, or requests for the database to gather and display information from a defined set of data. Queries of all data were selected by the user to be sorted and filtered. In addition, queries can combine information from one or more separate tables. For example, to examine the relationship between stream discharge and water temperature or any other combination of variables, a query could be designed to gather the necessary information from the two individual tables that store water quality data and stream discharge data separately.

4.3 Considerations for Model Input Parameters

Air temperature data were used as an input parameter for the models used to estimate each alternative’s effects on surface water quality. Data were obtained from stations that are part of the National Oceanic and Atmospheric Administration (NOAA) and National Weather Service (NWS) Co-operative Observer’s Program (Co-op). Given the spatial distribution of the Co-op stations throughout the project area, not all locations are close to USGS stream gages selected for model development. As a result, data were applied from a neighboring Co-op station for stream gages that did not share a location with a Co-op station (**Table M-4.1**).

Table M-4.2 portrays historical climate data obtained from the National Oceanic and Atmospheric Administration (NOAA). Data are listed according to USGS Station ID and corresponding station name. Based on their location within the project area, USGS stream gages were paired with a NOAA Co-op climate station. NOAA Co-op station identification numbers and corresponding co-op gage names are included for those locations where data were collected from the period indicated by the “begin” and end “dates”. Shaded rows (gray) mark those locations where climate data were not available. At those gages that do not have a paired co-op station, climate data from the closes climate station were applied (e.g. Socorro climate data were applied for the San Acacia stream gages).

Regression equations were devised based on two constants and the NOAA air temperature data from the gage closest to the unknown gages. The regression equation used is:

$$\text{NOAA air temperature (for gage without data)} = K_1 + K_2 * \text{(NOAA Gage air temperature)}$$

Where: K_1 and K_2 are constants and NOAA Gage air temperature is the air temperature at the closest gage on the day or time requested. The regression constant values (K_1 and K_2) are listed for gages with air temperatures. R^2 values are also listed for the regressions. See table **M-4.2** for constant values.

Table M-4.1. Historical NOAA climatic data

USGS Station ID	USGS Station Name	NOAA Co-op ID	NOAA Co-op Gage Name	Begin	End
8251500	RIO GRANDE NEAR LOBATOS, CO	055322-5	Manassa	1975	2003
8276500	RIO GRANDE BLW TAOS JUNCTION BRIDGE NR TAOS, NM		Applied Manassa Data		
8286500	RIO CHAMA ABOVE ABIQUIU RE, NM	290041-2	Abiquiu Dam	1975	2003
8287000	RIO CHAMA BL ABIQUIU DAM, NM	290041-2	Abiquiu Dam	1975	2003
8290000	RIO CHAMA NEAR CHAMITA, NM		Applied Abiquiu Data		
8313000	RIO GRANDE AT OTOWI BRIDGE, NM		Applied Abiquiu Data		
8319000	RIO GRANDE AT SAN FELIPE, NM		Applied Albuquerque Data		
8329000	JEMEZ RIVER BELOW JEMEZ CANYON DAM, NM		Applied Albuquerque Data		
8330000	RIO GRANDE AT ALBUQUERQUE, NM	290234-5	Albuquerque Intl. Airport	1975	2003
8332010	RIO GRANDE FLOODWAY NEAR BERNARDO, NM	298387-5	Socorro	1975	2003
8354800	CONVEYANCE CHANNEL AT SAN ACACIA, NM		Applied Socorro Data		
8354900	FLOODWAY AT SAN ACACIA, NM		Applied Socorro Data		
8358300	RIO GRANDE CONVEYANCE CHANNEL AT SAN MARCIAL, NM	291138-5	Bosque Del Apache	1975	2003
8358400	RIO GRANDE FLOODWAY AT SAN MARCIAL, NM	291138-5	Bosque Del Apache	1975	2003
8361000	RIO GRANDE BELOW ELEPHANT BUTTE DAM, NM	292848-5	Elephant Butte Dam	1975	2003
8363500	RIO GRANDE AT LEASBURG DAM, NM		Applied El Paso Data		
8364000	RIO GRANDE AT EL PASO, TX	412797-5	El Paso Intl. Airport	1975	2003
8370500	RIO GRANDE AT FORT QUITMAN, TX	413266-5	Fort Hancock	1989	2003

Table M-4.2. Gages without NOAA air temperature data and gages with NOAA air temperature data are listed

Gages without data			Gages with data	
Station ID	**K_1**	**K_2**	**NOAA Gage**	**R^2_{adj}**
8276500	6.272	0.941	8251500	0.626
8290000	5.231	0.836	8287000	0.688
8313000	5.849	0.917	8287000	0.755
8319000	4.706	0.857	8287000	0.819
8329000	3.615	1.02	8287000	0.836
8354800	4.462	1.053	8332010	0.821
8354900	5.462	1.001	8332010	0.787
8363500	-1.135	1.058	8364000	0.818

4.4 Methodology

The Water Quality Team utilized linear regression models developed for selected water quality variables at locations evenly distributed throughout the Project Area to analyze potential impacts to water quality from different water management scenarios. Regression is a statistical estimation theory used to estimate the value of a variable "*Y*" for a corresponding input of "*X*". This approach uses a numerical equation to represent the statistical relationship between the input variables and the estimated result. Given the need to estimate the outcome of a particular set of conditions, regression is commonly used by federal agencies to simulate surface water quality for planning and management purposes.

Water quality, climate, and discharge data were queried from tables to create a refined dataset for model development. Given data availability (see Section #. 3.1.1), only a select number of gages were used to develop surface water quality models (**Table M-4.3).** Stream gages selected for model development are distributed throughout the project area to ensure that each stream reach would be represented during the modeling process.

Table M-4.3. Stream gages selected for surface water quality model development. Gages are listed according to stream section, stream name, and corresponding USGS stream gage number

Section	Station Name	Gage No.
Chama	RIO CHAMA NEAR CHAMITA, NM	8290000
Chama	RIO GRANDE AT OTOWI BRIDGE, NM	8313000
Central	RIO GRANDE AT ALBUQUERQUE, NM	8330000
Central	RIO GRANDE FLOODWAY NEAR BERNARDO, NM	8332010
San Acacia	RIO GRANDE FLOODWAY AT SAN ACACIA, NM	8354900
San Acacia	RIO GRANDE FLOODWAY AT SAN MARCIAL, NM	8358400
Southern	RIO GRANDE BELOW ELEPHANT BUTTE DAM, NM	8361000

4.4.1 Assumptions

The following assumptions form the framework used for developing surface water quality models described in this document:

- Mean daily stream discharge, as reported by the U.S. Geological Survey, was used to develop the historical relationship between water quality variables and discharge.

- All boundary conditions except for stream discharge and air temperature were assumed constant for model development. This assumption can both overestimate and underestimate a given water quality variable because the mean daily discharge could be above or below the instantaneous conditions during which the water quality variable was sampled.
- Output data from URGWOM were used as input data for stream discharge for estimating potential effects on water quality for the 40-year sequence.
- Input data for air temperature were assigned using the historical time-series reconstruction developed for URGWOM (RM-49 SSP&A 2002).

4.4.2 Regression Model Development

General linear models (GLM) were used to build linear equations to describe the effects of alternatives on surface water quality. For each linear model, correlation for a given dependent variable (e.g. water temperature) and several independent variables (e.g. discharge, air temperature, reservoir storage) was measured. The significance of models and variables were assessed using p-values at a level of alpha = 0.05.

Output for each model included a numerical equation, corresponding R-square statistic, a P-value statistic for each model variable, a saved dataset for model residuals, plus all the variables in a data file for each GLM. Based on these results, individual model equations were compiled into a database table according to stream gage and water quality constituent. **Table M-4.4** displays the numerical equations (models) developed for the alternatives analysis.

Numerical models developed by the Water Quality Team are listed according to each stream gage and water quality constituent where:

- Discharge = mean daily stream discharge (cfs)
- Mean air temperature = air temperature (°C)
- Corrected air temperature = air temperature (°C) from corrected gage
- Heron Storage = storage (acre feet) in Heron Reservoir
- El Vado Storage = storage (acre feet) in El Vado Reservoir
- Abiquiu Storage = storage (acre feet) in El Vado Reservoir
- Jemez Storage = storage (acre feet) in Jemez Reservoir
- Elephant Butte Storage = storage (acre feet) in Elephant Butte Reservoir
- Galisteo Dam Gage = mean daily stream discharge (cfs) at Galisteo Creek
- Embudo Gage = mean daily stream discharge (cfs) at Embudo
- Alameda Gage = mean daily stream discharge at (cfs) North Floodway
- Rio Puerco Gage = mean daily stream discharge at (cfs) Rio Puerco
- Precipitation = mean daily precipitation (cm)

Table M-4.4. Numerical models developed by the Water Quality Team by gage and water quality constituent

Gage Number	Water Quality Constituent	Regression Equations Used for Water Quality Models
8290000	DO (mg/L)	(12.926 + -0.203 * Log([Disch_lng]) + -0.201 * (4.344334 + -0.642233 * Log([Disch_lng] + 1) + -0.009264 * ([Abiquiu_Storage_dbl]/1000) + 0.801037 * [CorrectedTmeanC_dbl]))
8290000	Water Temp (C)	(4.344334 + -0.642233 * Log([Disch_lng] + 1) + -0.009264 * ([Abiquiu_Storage_dbl]/1000) + 0.801037 * [CorrectedTmeanC_dbl])
8290000	TDS (mg/L)	(577.468421+-40.773859 * Log([Disch_lng] + 1) + -0.230006 * ([Heron_Storage_dbl]/1000) + -0.153306 * ([Abiquiu_Storage_dbl]/1000))
8313000	DO (mg/L)	(14.465 + -0.365 * Log([Disch_lng]) + -0.201 * (4.534 + -0.725 * Log([Disch_lng]) + 0.776 * [CorrectedTmeanC_dbl]))
8313000	Water Temp (C)	(4.534 + -0.725 * Log([Disch_lng]) + 0.776 * [CorrectedTmeanC_dbl])
8313000	TDS (mg/L)	iif([Disch_lng] is not null, EXP(6.813335 + -0.040313 * Log([Disch_lng] + 1) + -0.170420 * Log([St8279500_AltDisch_lng])+ -0.000340 * ([Heron_Storage_dbl] / 1000)) -1)
8330000	DO (mg/L)	(2.678 + 0.009 * Log([Disch_lng]) + -0.224 * Log(9.062 + -0.799 * Log([Disch_lng]) + 0.684 * [TmeanC_dbl]))
8330000	Water Temp (C)	(9.062 + -0.799 * Log([Disch_lng]) + 0.684 * [TmeanC_dbl])
8330000	TDS (mg/L)	EXP(5.660382 + -0.064791 * Log([St8329900_AltDisch_lng] + 1) + 0.089786 * Log([St8317950_AltDisch_lng] + 1) + -0.000459 * ([Abiquiu_Storage_dbl] / 1000) + -0.000098 * [Disch_lng]) - 1
8332010	DO (mg/L)	(16.478086 + -2.446696 * Log(2.273849 + -0.663190 * Log([Disch_lng] + 1) + 0.010711 * ([Heron_Storage_dbl]/1000) + 0.017583 * ([ElVado_Storage_dbl]/1000) + 0.790961 * [TmeanC_dbl]) + -0.163340 * Log([Disch_lng] + 1))
8332010	Water Temp (C)	(2.273849 + -0.663190 * Log([Disch_lng] + 1) + 0.010711 * ([Heron_Storage_dbl]/1000) + 0.017583 * ([ElVado_Storage_dbl]/1000) + 0.790961 * [TmeanC_dbl])
8332010	TDS (mg/L)	EXP(7.338 + -0.122 * Log([Disch_lng] + 1) + -0.106 * Log([St8279500_AltDisch_lng] +1) + -0.008 * [TmeanC_dbl]) - 1
8354900	DO (mg/L)	(10.904 + 0.104 * Log([Disch_lng] + 1) + -0.163 * (Log([St8353000_AltDisch_lng] + 1)) + -0.140 * ([TmeanC_dbl]))
8354900	Water Temp (C)	(0.299168 +- 0.377405*Log([Disch_lng]+1)+0.004423*[St8353000_AltDisch_lng]+0.017799*([ElVado_Storage_dbl]/1000)+0.772733*[CorrectedTmeanC_dbl])
8354900	TDS (mg/L)	(6.069975 + 0.000919 * [St8353000_AltDisch_lng] + -0.000167 * [Disch_lng])
8358400	DO (mg/L)	EXP(2.655 + -0.009 * Log([Disch_lng]) + -0.015 * Log([St8353000_AltDisch_lng] +1) + -0.021 * (5.741 + -0.330 * Log([Disch_lng]) + 0.775 * [TmeanC_dbl]))
8358400	Water Temp (C)	(5.741 + -0.330 * Log([Disch_lng]) + 0.775 * [TmeanC_dbl])
8358400	TDS (mg/L)	EXP(7.594628 + 0.052140 * Log([St8353000_AltDisch_lng] + 1) + -0.232945 * Log([Disch_lng] + 1) + -0.007967 * (5.741 + -0.330 * Log([Disch_lng]) + 0.775 * [TmeanC_dbl]))

Gage Number	Water Quality Constituent	Regression Equations Used for Water Quality Models
8361000	DO (mg/L)	(15.562992 + -0.338498 * Log([Disch_lng] + 1) + -0.346743 * [TmeanC_dbl])
8361000	Water Temp (C)	(15.058817 + -0.000529 * [Disch_lng] + 0.006028 * [St8353000_AltDisch_lng] + -1.779146 * Log([ElephantButte_Storage_dbl]/1000) + 0.629959 * [TmeanC_dbl])

4.5 Model Performance

Of the eighteen (18) gages selected for predictive water quality model development (**Table M-4.4**), only seven (7) gages for selected water quality constituents were included in the alternatives analysis process (**Table M-4.5**). Selected gages used to evaluate alternatives based on data availability (Section #.3.1.1). The Northern Section was not selected, as conditions would not be affected by each of the seven alternatives. The water quality constituents dissolved oxygen (DO), water temperature, and total dissolved solids (TDS) are marked for each gage where the individual constituent was used as part of the Alternatives evaluation. Blank boxes indicate that a given water quality was not used to evaluate Alternatives for a given gage.

Table M-4.5. Gages selected to evaluate alternatives

Section	Station Name	Station Name	Gage No.	DO	Water Temperature	TDS
Chama	Rio Chama near Chamita, NM	Chamita	8290000	x	x	x
Chama	Rio Grande At Otowi Bridge, Nm	Otowi	8313000	x	x	x
Central	Rio Grande At Albuquerque, Nm	Albuquerque	8330000		x	x
Central	Rio Grande Floodway Near Bernardo, Nm	Bernardo	8332010	x	x	x
San Acacia	Rio Grande Floodway At San Acacia, Nm	San Acacia	8354900	x	x	x
San Acacia	Rio Grande Floodway At San Marcial, Nm	San Marcial	8358400	x	x	x
Elephant Butte-Caballo	Rio Grande Below Elephant Butte Dam, Nm	Elephant Butte Dam	8361000	x	x	

Based on data availability and r-square values (RM-35 Ramsey and Schafer 1997) for each model (**Tables M-4.6a – M-4.6c**), these seven locations exhibit the highest correlation between the dependent and independent variables used to develop the models. P-values (RM-35 Ramsey and Schafer 1997) for each model input parameter were used to quantify the significance of individual model input parameters. All models used for alternatives analysis are significant at alpha=0.05, but not at the alpha=0.01 level.

Model output was compared to historical data using the time-series reconstruction defined for the URGWOM process (RM-54 SSP&A 2002). As a preliminary evaluation of model performance, this comparison illustrated whether or not the models were over or under estimating the effects of discharge on water quality constituents (**Figure M-4.1a-g**). Provided that the future 40-year sequence consists of a synthetic flow sequence using historical data re-arranged by year (RM-54 SSP&A 2002), the same method was used to match historic data with a corresponding sample in the future 40-year sequence. Using this reconstruction, historical data were compared with modeled data to evaluate the performance of the model.

Relationship between historic water quality constituents and modeled output for the USGS stream gage at Otowi, New Mexico are indicated in a series of figures. The historic measurements are matched to future estimates over the 40-year sequence using the time series reconstruction defined for URGWOM (M-54 SSP&A 2002). Figures for each of the alternatives are provided: No-Action Alternative (**Figure M-4.1a**), Alternative B (**Figure M-4.1b**), Alternative D (**Figure**

M-4.1c), Alternative E (**Figure M-4.1d**), Alternative I-1 (**Figure M-4.1e**), Alternative I-2 (**Figure M-4.1f**), and Alternative I-3 (**Figure M-4.1g**).

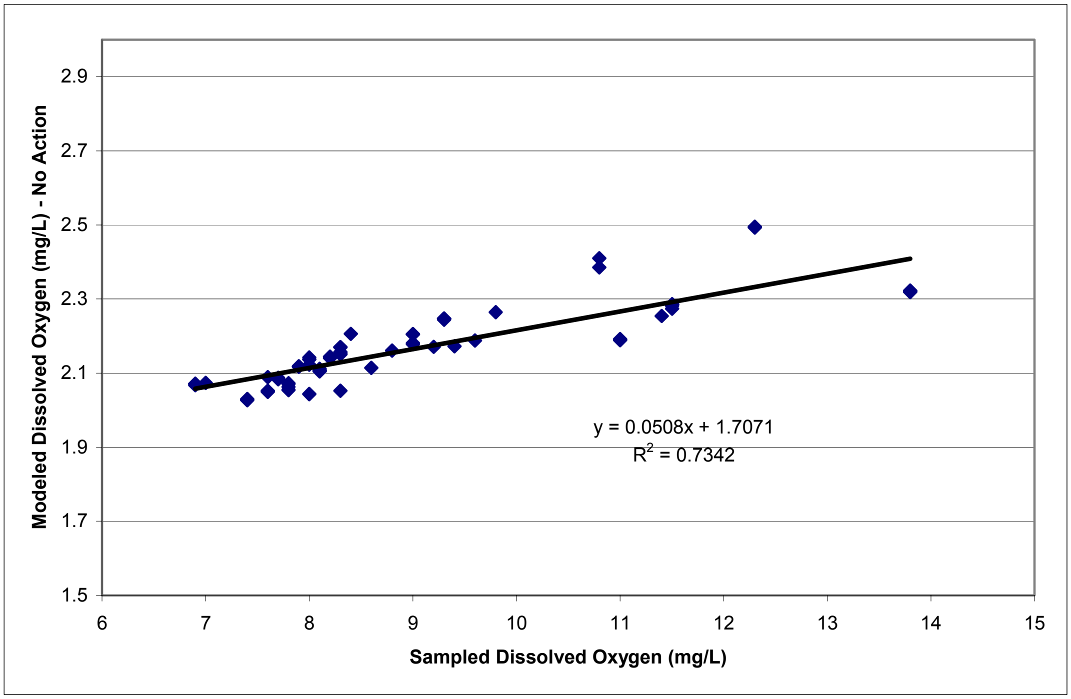

Figure M-4.1a . No Action relationship between historic and modeled dissolved oxygen at Otowi, NM.

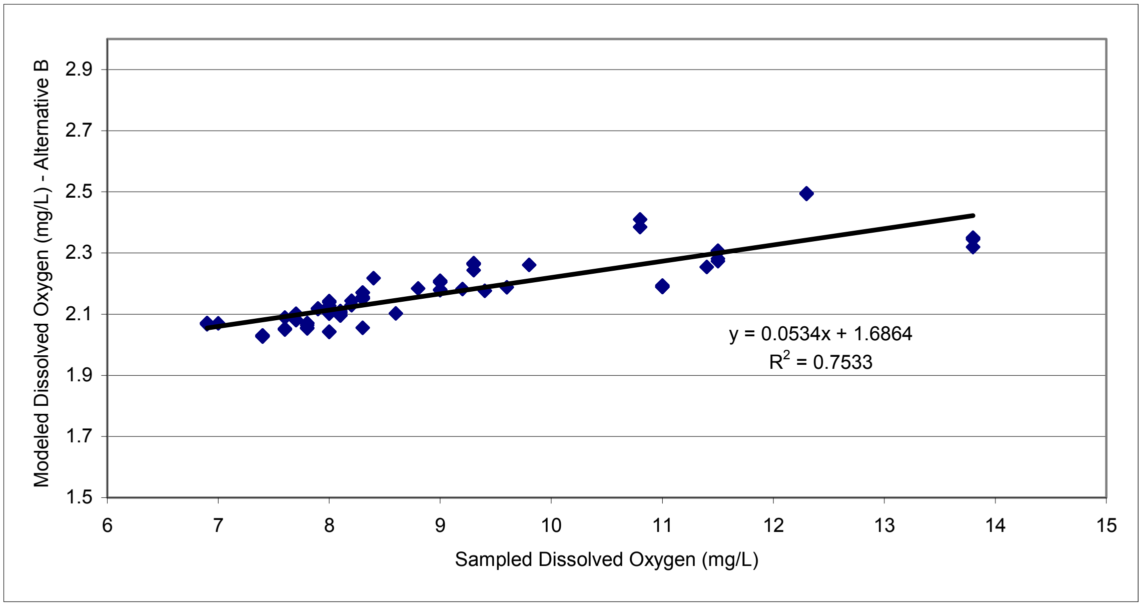

Figure M-4.1b. Alternative B-3 relationship between historic and modeled dissolved oxygen at Otowi, NM.

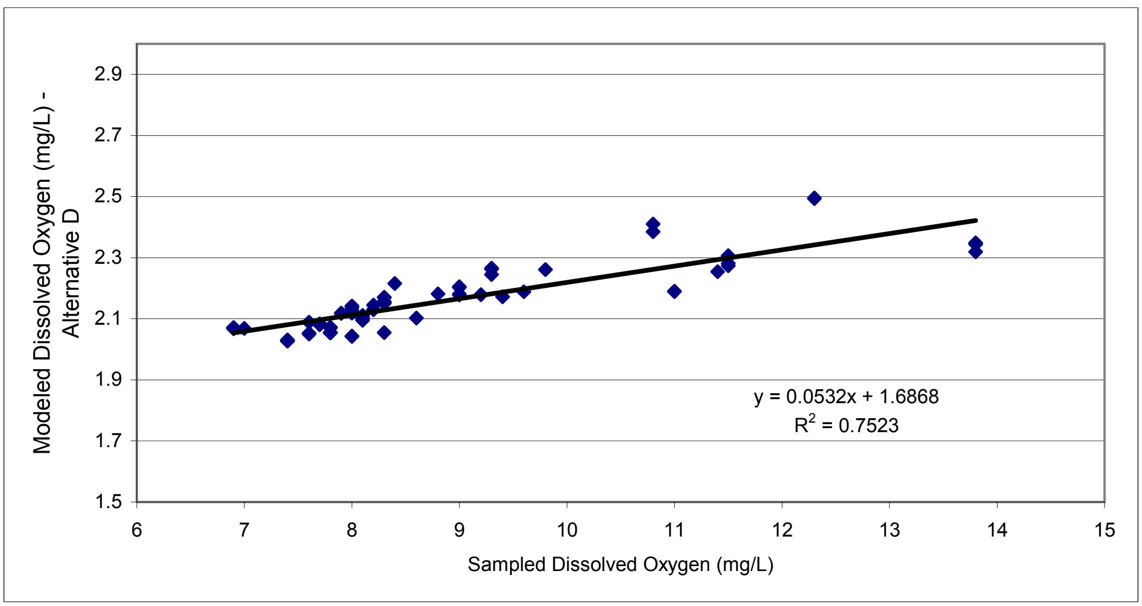

Figure M-4.1c. Alternative D-3 relationship between historic and modeled dissolved oxygen at Otowi, NM.

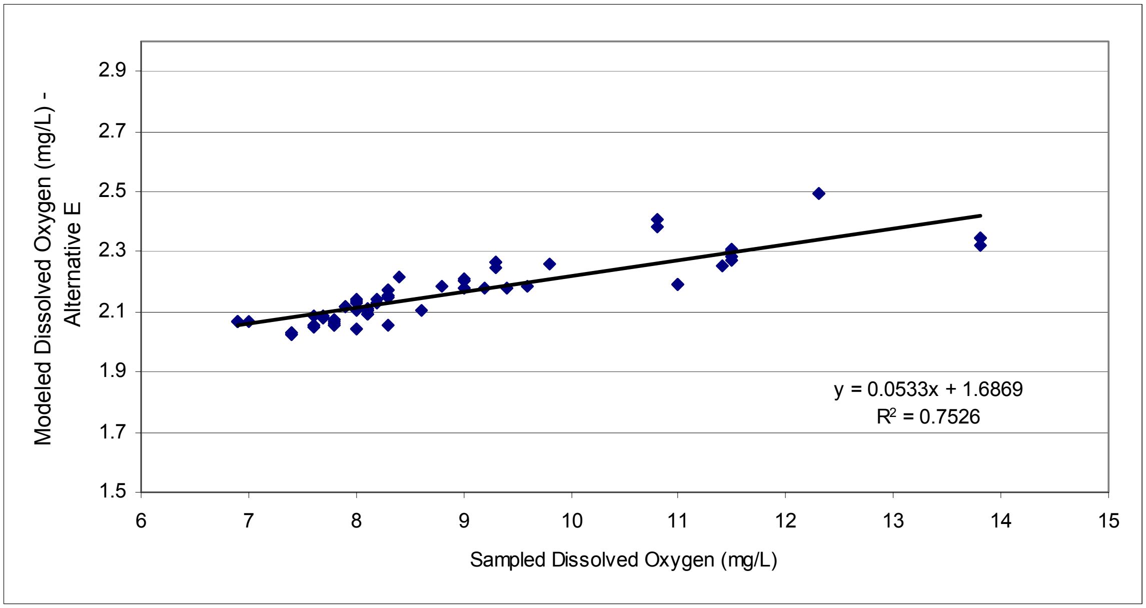

Figure M-4.1d. Alternative E-3 relationship between historic and modeled dissolved oxygen at Otowi, NM.

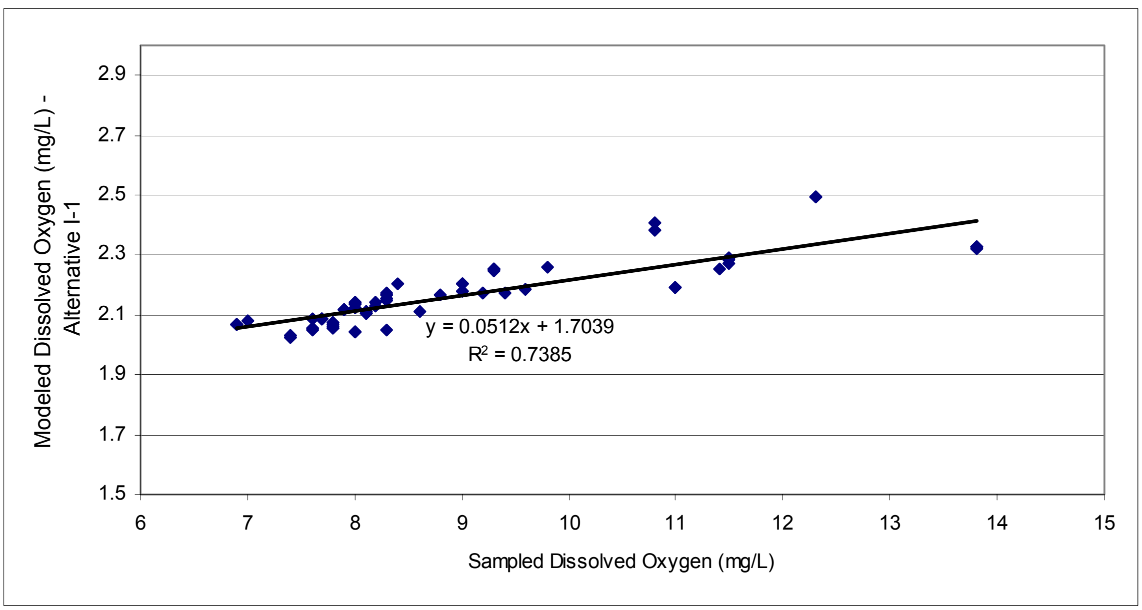

Figure M-4.1e. Alternative I-1 relationship between historic and modeled dissolved oxygen at Otowi, NM.

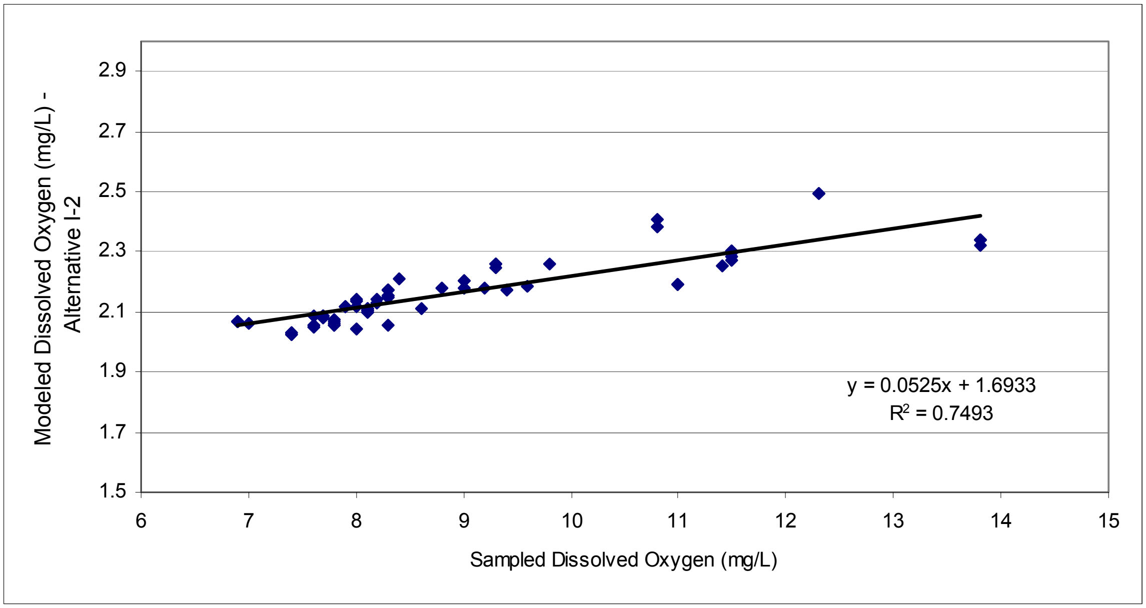

Figure M-4.1f. Alternative I-2 relationship between historic and modeled dissolved oxygen at Otowi, NM.

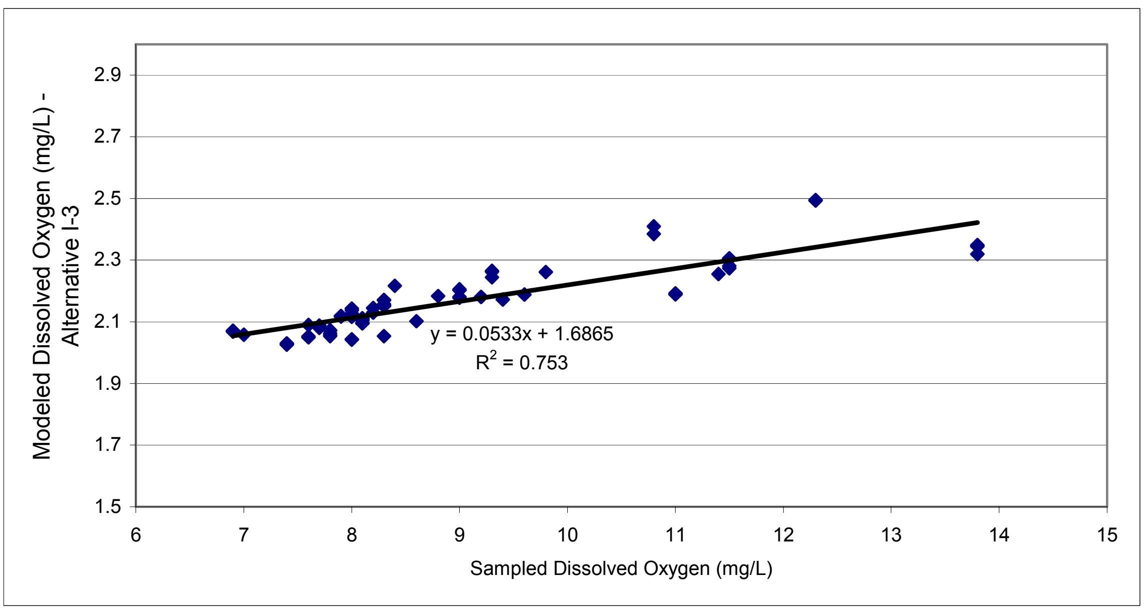

Figure M-4.1g. Alternative I-3 relationship between historic and modeled dissolved oxygen at Otowi, NM.

Table 4.6a. Data availability, variables, r-square value, and n for dissolved oxygen by gage

Dissolved Oxygen (mg/L)

Section	Station ID	Station Name	Variable	Variable Value (P-Value)	r-square	n
			Constant	12.93 (<0.0001)		
			log[Discharge (cfs) + 1]	-0.20 (<0.0001)		
Chama	8290000	RIO CHAMANEAR CHAMITA, NM	Water Temperature	-0.20 (<0.0001)	0.86	93
			Constant	14.47 (<0.0001)		
			log[Discharge (cfs) + 1]	-0.37 (<0.0001)		
Chama	8313000	RIO GRANDE AT OTOWI BRIDGE, NM	Water Temperature	-0.20 (<0.0001)	0.77	186
			Constant	2.68 (<0.0001)		
			log[Discharge (cfs) + 1]	0.01 (<0.0001)		
Central	8330000	RIO GRANDE AT ALBUQUERQUE, NM	Water Temperature	-.22 (<0.0001)	0.74	44
			Constant	10.90 (<0.0001)		
			log[Discharge (cfs) + 1]	0.11 (0.13)		
			Mean Daily Temperature	-0.14 (<0.0001)		
San Acacia	8354900	RIO GRANDE FLOODWAY AT SAN ACACIA, NM	log [Rio Puerco Discharge (cfs) +1]	-0.16 (0.001)	0.74	88
			Constant	14.22 (<0.0001)		
			log[Discharge (cfs) + 1]	0.99 (0.05)		
			Water Temp	0.98 (<0.0001)		
San Acacia	8358400	RIO GRANDE FLOODWAY AT SAN MARCIAL, NM	log[Rio Puerco Discharge (cfs) + 1]	0.99 (<0.0001)	0.85	148
			Constant	15.56 (<0.0001)		
			log[Discharge (cfs) + 1]	-0.3385 (0.01)		
Southern	8361000	RIO GRANDE BELOW ELEPHANT BUTTE DAM, NM	Mean Daily Temperature	-0.35 (<0.0001)	0.61	72

Table M-4.6b. Data availability, variables, r-square value, and n for TDS by gage

Section	Station ID	Station Name	Variable	Variable Value (P-Value)	r-square	n
			Constant	577.47 (<0.0001)		
			log[Discharge (cfs) + 1]	-40.77 (<0.0001)		
			Heron Storage (1000 ac-ft)	-0.23 (0.0002)		
Chama	8290000	RIO CHAMANEAR CHAMITA, NM	Abiquiu Storage (1000 ac-ft)	-0.15 (0.03)	0.60	208
			Constant	906.87 (<0.0001)		
			log[Discharge (cfs) + 1]	0.96 (0.05)		
			Heron Storage (1000 ac-ft)	-.01 (0.0001)		
Chama	8313000	RIO GRANDE AT OTOWI BRIDGE, NM	log[Embudo Discharge (cfs) + 1]	-0.17 (<0.0001)	0.61	264
			Constant	287.26 (<0.0001)		
			log[Discharge (cfs) + 1]	-0.01 (<0.0001)		
			Abiquiu Storage (1000 ac-ft)	-0.01 (0.07)		
			log [Galisteo Discharge (cfs) + 1]	0.09 (0.0003)		
Central	8330000	RIO GRANDE AT ALBUQUERQUE, NM	log [Rio Jemez Discharge (cfs) + 1]	0.94 (0.002)	0.41	75
			Constant	1537.63 (<0.0001)		
			log[Discharge (cfs) + 1]	0.89 (<0.0001)		
			TmeanC_dbl	-0.01 (<0.0001)		
Central	8332010	RIO GRANDE FLOODWAY NEAR BERNARDO, NM	log[Embudo Discharge (cfs) + 1]	-0.11 (<0.0001)	0.73	201
			Constant	6.07 (<0.0001)		
			log[Discharge (cfs) + 1]	-0.01 (<0.0001)		
San Acacia	8354900	RIO GRANDE FLOODWAY AT SAN ACACIA, NM	log[Rio Puerco Discharge (cfs) + 1]	0.01 (<0.0001)	0.54	109
			Constant	1987.49 (<0.0001)		
			log[Discharge (cfs) + 1]	0.79 (<0.0001)		
			Water Temp	0.99 (<0.0001)		
San Acacia	8358400	RIO GRANDE FLOODWAY AT SAN MARCIAL, NM	log[Rio Puerco Discharge (cfs) + 1]	1.05 (<0.0001)	0.58	429
			Constant	1919.85 (<0.0001)		
			log[Discharge (cfs) + 1]	0.99 (0.03)		
			log[ElephantButte_Storage (1000 ac-ft)]	-0.24 (<0.0001)		
Elephant Butte	8361000	RIO GRANDE BELOW ELEPHANT BUTTE DAM, NM	Precipitation (in/day)	-0.17 (0.002)	0.59	228

Table M-4.6c. Data availability, variables, r-square value, and n for water temperature by gage

Section	Station ID	Station Name	Variable	Variable Value (P-Value)	r-squared	n
Water Temp (C)						
			Constant	4.344 (0.0002)		
			log[Discharge (cfs) + 1]	-0.642 (0.003)		
			Mean Daily Temperature	0.801 (<0.0001)		
Chama	8290000	RIO CHAMANEAR CHAMITA, NM	Abiquiu Storage (1000 acre-ft)	-0.009 (0.001)	0.76	197
			Constant	4.53 (0.001)		
			log[Discharge (cfs) + 1]	-0.73 (<0.0001)		
Chama	8313000	RIO GRANDE AT OTOWI BRIDGE, NM	Mean Daily Temperature	0.78 (<0.0001)	0.86	290
			Constant	9.06 (<0.0001)		
			log[Discharge (cfs) + 1]	-0.80 (<0.0001)		
Central	8330000	RIO GRANDE AT ALBUQUERQUE, NM	Mean Daily Temperature	0.68 (<0.0001)	0.81	456
			Constant	2.27 (0.23)		
			log[Discharge (cfs) + 1]	-0.66 (<0.0001)		
			Mean Daily Temperature	0.79 (<0.0001)		
			Heron Storage (1000 acre-ft)	0.01 (0.03)		
Central	8332010	RIO GRANDE FLOODWAY NEAR BERNARDO, NM	El Vado Storage (1000 acre-ft)	0.02 (0.003)	0.86	309
			Constant	0.30 (0.71)		
			log[Discharge (cfs) + 1]	-0.38 (<0.0001)		
			Mean Daily Temperature	0.77 (<0.0001)		
			El Vado Storage (1000 acre-ft)	0.18 (0.001)		
San Acacia	8354900	RIO GRANDE FLOODWAY AT SAN ACACIA, NM	log[Rio Puerco Discharge (cfs) + 1]	0.01 (0.003)	0.85	305
			Constant	5.741 (<0.0001)		
			log[Discharge (cfs) + 1]	-0.33 (0.003)		
San Acacia	8358400	RIO GRANDE FLOODWAY AT SAN MARCIAL, NM	Mean Daily Temperature	0.775 (<0.001)	0.78	651
			Constant	15.06 (<0.0001)		
			log[Discharge (cfs) + 1]	-0.01 (0.08)		
			Mean Daily Temperature	0.63 (<0.001)		
Southern	8361000	RIO GRANDE BELOW ELEPHANT BUTTE DAM, NM	log[ElephantButte_Storage (1000 ac-ft)]	-0.24 (<0.0001)	0.6	280

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5.0 Alternative Impacts on Water Quality

5.1 Impacts on Preserving Water Quality

Reservoirs create a thermal regime similar to lakes, where the surface layer will be warmer than the river water before impoundment, and the deeper waters of the reservoir may be much cooler than the river surface water downstream. The amount of water discharged from a dam and water temperature has a synergistic affect on a number of other constituents, eventually riverine water quality begins to reflect atmospheric conditions, anthropogenic influences, and geology. Latitude and geographic location also play a prominent role, affecting water quality constituents throughout the Basin from north to south. Variations in operational management of reservoirs and dams will not only affect current water quality conditions below the dams but also conditions in the reservoirs.

Model results were weighted according to project-specific decision support software requirements. Weights were developed for water temperature, dissolved oxygen, and total dissolved solids by the WQRT for each reach and section in the project area according to data availability, model performance, and expert knowledge of water quality conditions and responses (**Table M-5.1**). Generally, data availability was best for water temperature and dissolved oxygen and those constituents were weighted more heavily than total dissolved solids. Weights were not developed for the entire Southern Section because of data limitations and lack of URGWOM model data. Rather, weights were only developed in the Southern Reach for dissolved oxygen and water temperature for the reach immediately downstream of Elephant Butte Dam. TDS weights were not used for this reach because of lack of suitable data for model development.

Model results were used to determine the percentage of days during the 40-year series with predicted water quality conditions that comply with water quality standards. Decision support weights were applied to the percent compliance to determine the alternatives that best preserve water quality throughout the project area. The alternative that best preserves water quality conditions was selected using model output and decision support weights after consideration was given to mitigative flexibilities that exist for reservoir storage and discharge for each alternative.

Quantitative predictive models were developed to assess indicators of water quality within the EIS. Overall model scores and rankings are indicated in **Table M-5.2**. Indicators included water quality constituents dissolved oxygen, surface water temperature, and total dissolved solids (TDS), and adaptive mitigative flexibility. Weighted values for each river section by criterion can be found in **Figure M-5.1** Modeled water quality constituents were selected based on data availability. These constituents were applied to the project area, which was divided into four primary sections: the Chama, Central, San Acacia and Southern. The Chama Section combined modeled output from the Chamita and Otowi gages; the Central Section combined the Central and Bernardo gages; the San Acacia Section combined the San Acacia and San Marcial gages; and the Southern Section included only data from the Below Elephant Butte Dam gage because there was a lack of suitable historic data and modeled URGWOM data at other USGS gages below Elephant Butte Dam. The Northern Section was not selected for water quality analysis because there would be no change in operations from current conditions.

Table M-5.1. Water quality weighted values by river section and criterion

Section	Criterion	Percent	Normalized	
Chama	Dissolved Oxygen	12.50%	11.521	0.115207373
Central		10.00%	9.217	0.092165899
San Acacia		10.00%	9.217	0.092165899

Section	Criterion	Percent	Normalized	
Elephant Butte-Caballo		5.00%	4.608	0.046082949
Chama	Water Temperature	15.00%	13.825	0.138248848
Central		12.50%	11.521	0.115207373
San Acacia		12.50%	11.521	0.115207373
Elephant Butte-Caballo		5.00%	4.608	0.046082949
Chama	TDS/Conductivity	10.00%	9.217	0.092165899
Central		7.50%	6.912	0.069124424
San Acacia		7.50%	6.912	0.069124424
Elephant Butte-Caballo		0.00%	0.000	0
Conservation Flexibility		1.00%	0.922	0.00921659
		108.50%	100	

Table M-5.2. Overall scores and rankings for the WQRT

Alternative	Score	Rank
No Action	0.8792	7
Alt B	0.9627	1
Alt D	0.9415	4
Alt E	0.9419	3
Alt I1	0.9050	6
Alt I2	0.9335	5
Alt I3	0.9421	2

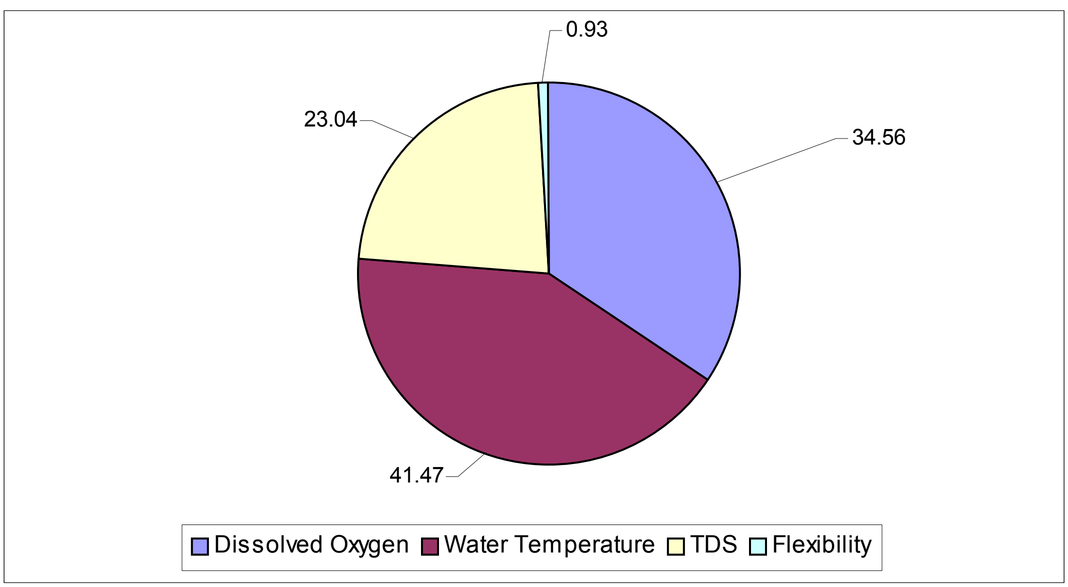

Figure M-5.1. Water quality model weighted values by criterion (water quality constituents).

5.2 Impacts of Future Without Action

5.2.1 Impacts on Water Quality

The modeled water quality data for the 40-year sequence were obtained using the No Action alternative as the baseline for comparison with the other alternatives. As modeled, the No Action alternative would provide the worst support for preserving water quality among the seven different alternatives. Adverse impacts varied by water quality constituent and river section. The current operations demonstrated support for maintaining dissolved oxygen through the four river sections. Of the modeled water quality constituents dissolved oxygen was most preserved under the No Action alternative, particularly along the Chama, San Acacia, and Elephant Butte-Caballo sections (**Figure M-5.2**). Dissolved oxygen is moderately affected through the Central Section under the No Action alternative. The No Action alternative is worst for preserving water temperature of the seven alternatives. Water temperature through the Chama and Elephant Butte-Caballo sections would be adversely impacted by the selection of the No Action alternative, while there would be no adverse affects on water temperature through the Central and San Acacia sections. TDS would only be affected through one river section under the No Action alternative. TDS would not be adversely affected through the Chama and Central sections, but would be adversely impacted through the San Acacia Section, particularly near San Marcial. There is no adaptive flexibility under the No Action alternative because there is no conservation storage.

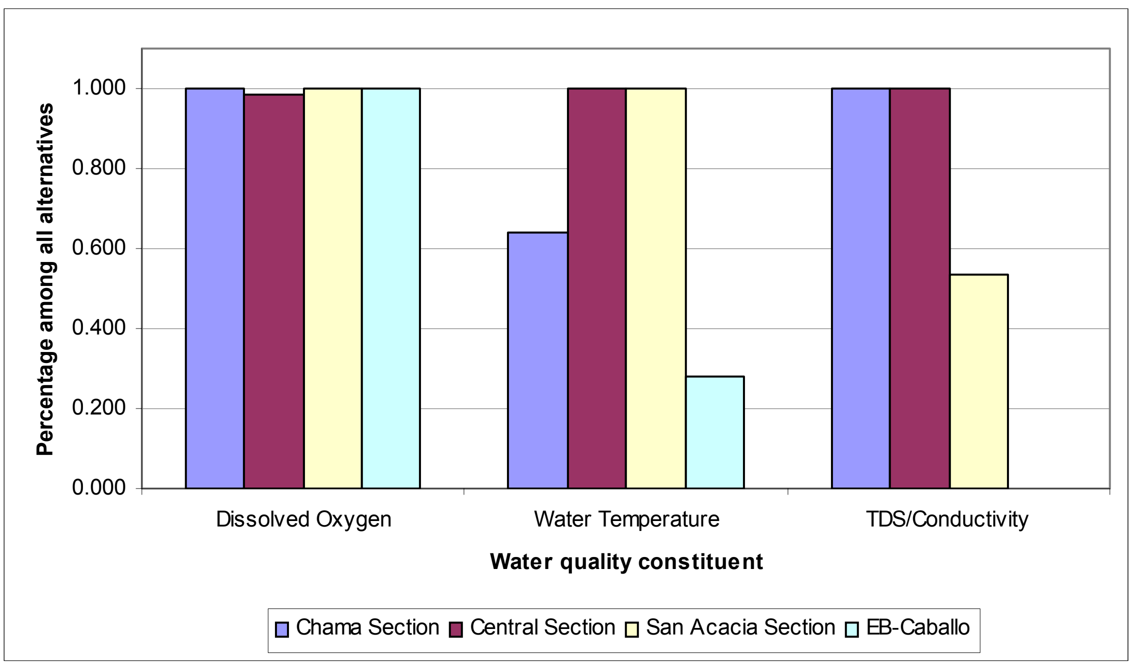

Figure M-5.2. Water Quality Impact - No Action Alternative.

5.3 Impacts of Alternative B-3

5.3.1 Impacts on Water Quality

The modeled water quality and subsequent data matrix model showed Alternative B-3 to best preserve overall water quality in the study area. Dissolved oxygen conditions would be most adversely affected by Alternative B-3. Dissolved oxygen along the Chama and San Acacia sections would not be adversely affected by Alternative B-3, while Alternative B-3 will most adversely affect dissolved oxygen along the

Central and Elephant Butte-Caballo sections. Variation among the different alternatives is relatively small though. The quality of water temperature is most preserved by Alternative B-3 within the Rio Grande system. Alternative B-3 would better preserve water temperature through the Chama and Elephant Butte-Caballo sections compared with No Action. There is no significant difference between water temperature through the Central and San Acacia sections when comparing No Action and Alternative B-3. There is no significant difference between TDS through the Chama and Central sections when comparing No Action and Alternative B-3, but there is a noticeable difference through the San Acacia Section. Alternative B-3 is the best alternative for preserving the quality of TDS in all sections, especially through the San Acacia Section. The alternative showed high levels of conservation storage compared to other alternatives, providing the most flexibility.

5.4 Impacts of Alternative D-3

5.4.1 Impacts on Water Quality

Alternative D-3 ranked fourth among the seven different alternatives for preserving water quality, performing at an intermediate level. The modeled results of Alternative D-3 closely resemble alternatives E-3 and I-3. Dissolved oxygen through the Chama and San Acacia sections would not be adversely affected by Alternative D-3. The Central Section would be moderately affected by this alternative, while the Elephant Butte-Caballo Section would be most adversely affected by selecting this alternative. No Action preserves dissolved oxygen better than Alternative D-3 through the Central and Elephant Butte-Caballo sections. Water temperature through the San Acacia and Elephant Butte-Caballo sections is not adversely affected, and is only moderately affected through the Chama and Albuquerque sections. Alternative D-3 has a minimum affect on preserving water temperature. There is no significant difference between water temperature through the Central and San Acacia sections when comparing No Action and Alternative D-3. Alternative D-3 does preserve water temperature better than No Action through the Chama and Elephant Butte-Caballo sections. TDS is not adversely affected by D-3 through the Chama and Central sections but is moderately affected through the San Acacia Section, especially near San Marcial. Adaptive flexibility under Alternative D-3 is considered average compared to the other alternatives.

5.5 Impacts of Alternative E-3

5.5.1 Impacts on Water Quality

The modeled water quality and subsequent data matrix model showed Alternative E-3 ranked third among the seven alternatives in preserving water quality in the study area. Alternative E-3 would not affect dissolved oxygen through the Chama and San Acacia sections, while it would moderately affect dissolved oxygen through the Central Section and adversely affect values through the Elephant Butte-Caballo Section compared to other alternatives. The No Action alternative would better preserve dissolved oxygen through the Elephant Butte-Caballo Section compared to Alternative E-3. Alternative E-3 would moderately affect water temperature through the Chama, Central, and Elephant Butte-Caballo sections. This alternative would not affect water temperature through the San Acacia Section. Alternative E-3 would better preserve water temperature through the Chama and Elephant Butte-Caballo sections when compared to No Action. TDS would be preserved through the Chama and Central sections and is moderately affected through the San Acacia Section. Alternative E-3 would better preserve TDS through the San Acacia Section when compared to No Action. Adaptive flexibility under Alternative E-3 is considered average compared to the other alternatives.

5.6 Impacts of Alternative I-1

5.6.1 Impacts on Water Quality

Alternative I-1 ranked sixth for preserving water quality among the seven different alternatives. Only No Action ranked worst in preserving water quality. Dissolved oxygen through the Chama, Central, and San Acacia sections is not adversely impacted by Alternative I-1, while the Elephant Butte-Caballo Section is only moderately affected by this alternative. Dissolved oxygen would be better preserved through the Central Section by Alternative I-1 when compared to No Action, while No Action would better preserve dissolved oxygen through the Elephant Butte-Caballo Section. Dissolved oxygen would be better preserved throughout the system than five of the other alternatives. Water temperature is preserved through the Central and San Acacia sections under I-1, but is negatively affected in the Chama and Elephant Butte-Caballo sections. This alternative proved to be the second worst of the seven different alternatives in preserving water temperature. Only No Action ranked worse than Alternative I-1. TDS is not adversely affected by I-1 through the Chama and Central sections, and is moderately affected through the San Acacia Section. Alternative I-1 would better preserve TDS through the San Acacia Section when compared to No Action. Adaptive flexibility under Alternative I-1 is considered minimal, ranking second worst of the modeled alternatives. Only No Action ranks worse than Alternative I-1.

5.7 Impacts of Alternative I-2

5.7.1 Impacts on Water Quality

The modeled water quality and subsequent data matrix showed Alternative I-2 ranked fifth among the seven alternatives in preserving water quality. Alternative I-2 would not negatively affect dissolved oxygen through the Chama and San Acacia sections, while it would moderately affect dissolved oxygen through the Central Section and adversely affect values through the Elephant Butte-Caballo Section. No Action better preserves dissolved oxygen through the Elephant Butte-Caballo Section when compared to Alternative I-2. Alternative I-2 negatively affects water temperature through the Chama Section; moderately affects water temperature through the Elephant Butte-Caballo Section; and preserves water temperature in the Central and San Acacia sections. Alternative I-2 would better preserve water temperature through the Chama and Elephant Butte-Caballo sections when compared to No Action. TDS would be preserved through the Chama and Central sections under this alternative. The San Acacia Section is moderately affected by this alternative. Alternative I-2 would better preserve TDS through the San Acacia Section when compared to No Action. Adaptive flexibility under Alternative I-2 is considered minimal, ranking third worst of the modeled alternatives. Only Alternative I-1 and No Action rank worse.

5.8 Impacts of Alternative I-3

5.8.1 Impacts on Water Quality

Alternative I-3 ranked second for preserving water quality among the seven different alternatives. **Figure M-5.3** portrays the difference in modeled output values between alternatives B-3 and I-3. The modeled results of Alternative I-3 closely resemble alternatives D-3 and E-3. Dissolved oxygen through the Chama and San Acacia sections would not be adversely impacted by Alternative I-3, while the Central section is moderately affected and the Elephant Butte-Caballo section is adversely affected. Alternative I-3 moderately preserves dissolved oxygen throughout the system. No Action would better preserve dissolved oxygen through the Elephant Butte-Caballo Section when compared to Alternative I-3. Water temperature is preserved through the San Acacia and Elephant Butte-Caballo sections under I-3, but is moderately affected through the Chama and Central sections. This alternative proved to be the second best in preserving water temperature, and would better preserve water temperature than No Action. TDS is not adversely affected by I-3 through the Chama and Central sections. Alternative I-3 would moderately affect TDS in the San Acacia Section. TDS would be better preserved under Alternative I-3 than the No Action alternative. Adaptive flexibility is considered adequate, ranking second only to Alternative B-3 of the seven alternatives.

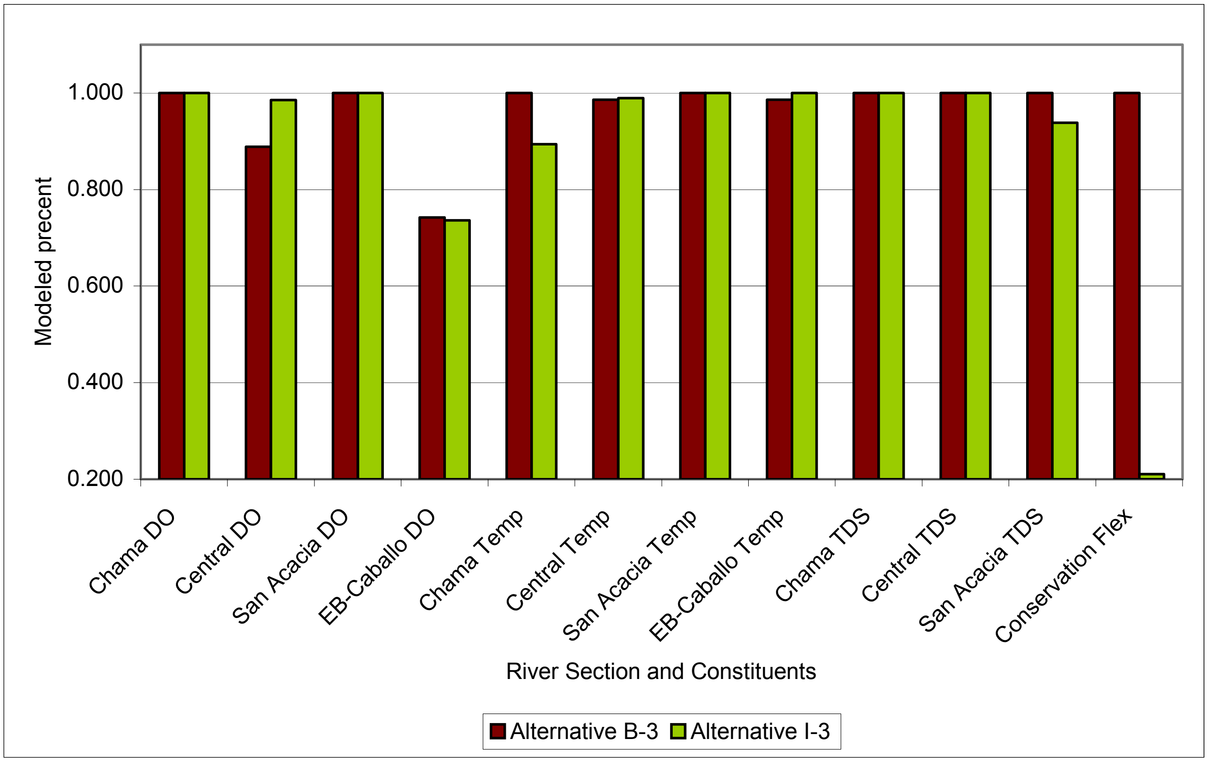

Figure M-5.3. A comparison of Alternative B-3 and Alternative I-3 by constituent and river section.

5.9 Comparison of Relative Impacts of All Alternatives

Many of the different operation alternatives proved to closely resemble each other following model output rankings, except for the No Action alternative which ranked seventh of seven alternatives. The three water quality constituents determined most of the criterion, although adaptive flexibility was also included in the weighted scheme. Relative impacts of all alternatives on preserving dissolved oxygen, water temperature, and TDS are listed in **Tables M-5.3a through M-5.3c**. The No Action alternative would be most detrimental to preserving water quality in the Rio Grande Basin. For this reason, all other alternatives are compared to No Action in **Figure M-5.4**. In **Figure M-5.4** negative values indicate that No Action would perform better than the alternatives listed, while positive values indicate an alternative would perform better than No Action. Only constituents and river sections where differences where identified are included in the figure.

The No Action alternative has the lowest rankings for overall water temperature and TDS, and provides no mitigative flexibility. Alternative B-3 ranked first of the seven alternatives although the model indicated it would be detrimental to dissolved oxygen in the Central and Elephant Butte-Caballo sections. Dissolved oxygen through the Chama and San Acacia sections was not affected by changes in operations. Dissolved oxygen was only affected through the Central and Elephant Butte-Caballo sections by changes in operations. Water temperature in the Rio Grande Basin would be most affected under the No Action alternative, followed by Alternative I-1. There is no affect on water temperature through the San Acacia Section under any of the operation alternatives. Alternative B-3 would best preserve water temperature of the alternatives. TDS is not affected by any of the alternatives through the Chama and Central sections, and was not modeled for the Elephant Butte-Caballo Section because of data availability. TDS would be most adversely affected by No Action, and most preserved by Alternative B-3. Similarly, adaptive flexibility is worst under No Action and best under Alternative B-3. Modeled output showed great similarities between alternatives D-3, E-3 and I-3. Alternatives D-3 and E-3 had average mitigative flexibility compared to the other alternatives, while Alternative I-1 and I-2 had poor mitigative flexibility compared to the other alternatives. The No Action alternative does not have any mitigative flexibility.

Table M-5.3a. Relative impacts of all alternatives on dissolved oxygen

Alternative	Impacts to Rio Chama Section	Impacts to Central Section	Impacts to San Acacia Section	Impacts to Elephant Butte-Caballo Section
No Action	Preserves	Moderate Adverse effects	Preserves	Preserves
Alternative B-3	Preserves	Significant adverse effects	Preserves	Significant adverse effects
Alternative D-3	Preserves	Moderate Adverse effects	Preserves	Significant adverse effects
Alternative E-3	Preserves	Moderate Adverse effects	Preserves	Significant adverse effects
Alternative I-1	Preserves	Preserves	Preserves	Moderate Adverse effects
Alternative I-2	Preserves	Moderate Adverse effects	Preserves	Significant adverse effects
Alternative I-3	Preserves	Moderate Adverse effects	Preserves	Significant adverse effects

Table M-5.3b. Relative impacts of all alternatives on water temperature

Alternative	Impacts to Rio Chama Section	Impacts to Central Section	Impacts to San Acacia Section	Impacts to Elephant Butte-Caballo Section
No Action	Significant adverse effects	Preserves	Preserves	Significant adverse effects
Alternative B-3	Preserves	Moderate Adverse effects	Preserves	Moderate Adverse effects
Alternative D-3	Moderate Adverse effects	Moderate Adverse effects	Preserves	Preserves
Alternative E-3	Moderate Adverse effects	Moderate Adverse effects	Preserves	Moderate Adverse effects
Alternative I-1	Significant adverse effects	Preserves	Preserves	Significant adverse effects
Alternative I-2	Significant adverse effects	Preserves	Preserves	Moderate Adverse effects
Alternative I-3	Moderate Adverse effects	Moderate Adverse effects	Preserves	Preserves

Table M-5.3c. Relative impacts of all alternatives on TDS

Alternative	Impacts to Rio Chama Section	Impacts to Central Section	Impacts to San Acacia Section	Impacts to Elephant Butte-Caballo Section
No Action	Preserves	Preserves	Significant adverse effects	Not modeled
Alternative B-3	Preserves	Preserves	Preserves	Not modeled
Alternative D-3	Preserves	Preserves	Moderate Adverse effects	Not modeled
Alternative E-3	Preserves	Preserves	Moderate Adverse effects	Not modeled
Alternative I-1	Preserves	Preserves	Moderate Adverse effects	Not modeled
Alternative I-2	Preserves	Preserves	Moderate Adverse effects	Not modeled
Alternative I-3	Preserves	Preserves	Moderate Adverse effects	Not modeled

Table M-5.4 portrays the percent of the time over the 40-year sequence water quality is preserved by constituent, river section, and alternative. The data appear to be similar but a difference of half-a-percent indicates a difference of 75 exceedence days over the forty-year sequence. For example, TDS through the San Acacia Section is preserved 93.6% of the time by Alternative B-3 and 93.5% of the time by Alternative D-3, but D-3 has 18 additional exceedence days over the forty-year sequence. Every tenth of a percent represents a difference of approximately fifteen days.

Table M-5.4. Percent during the 40-year sequence when water quality is preserved by alternative

Constituents by Reach	No Action	B-3	D-3	E-3	I-1	I-2	I-3
DO Chama	96.6%	96.6%	96.6%	96.6%	96.6%	96.6%	96.6%
DO Central	93.0%	92.7%	92.8%	92.8%	92.8%	92.8%	92.8%
DO San Acacia	94.5%	94.5%	94.5%	94.5%	94.5%	94.5%	94.5%
DO Elephant Butte-Caballo	63.0%	62.7%	62.7%	62.7%	62.9%	62.8%	62.7%
Temp Chama	97.5%	98.0%	97.9%	97.9%	97.6%	97.8%	97.9%
Temp Central	97.0%	97.0%	97.0%	97.0%	97.0%	97.0%	97.0%
Temp San Acacia	94.5%	94.5%	94.5%	94.5%	94.5%	94.5%	94.5%
Temp Elephant Butte-Caballo	96.1%	98.6%	98.6%	98.6%	97.6%	98.6%	98.6%
TDS Chama	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
TDS Central	97.1%	97.1%	97.1%	97.1%	97.1%	97.1%	97.1%
TDS San Acacia	92.8%	93.6%	93.5%	93.5%	93.6%	93.5%	93.5%
TDS Elephant Butte-Caballo	N/A	N/A	N/A	N/A	N/A	N/A	N/A

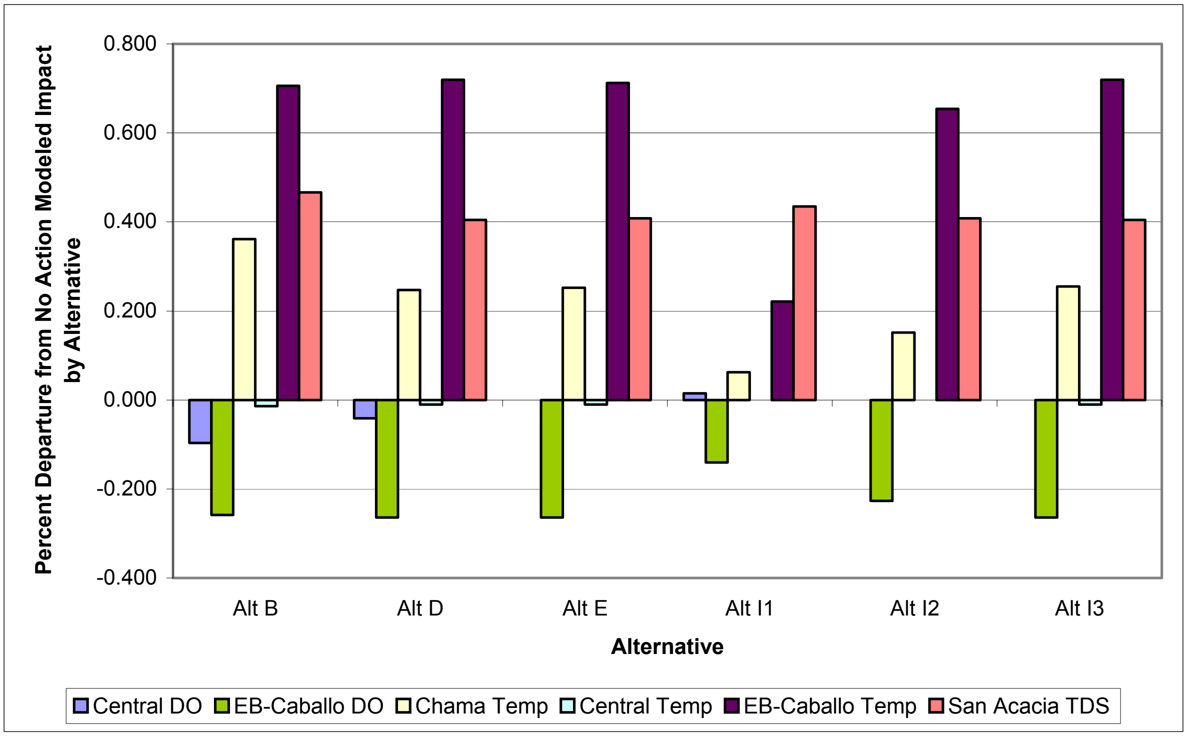

Figure M-5.4. Comparison of all alternatives to No Action.

5.10 Preferred Alternative and Net Impacts After Mitigation

The preferred alternative for the water quality team is Alternative B-3. Alternative B-3 ranks first when compared to No Action and the other alternatives (**Figure M-5.5**). Alternative B-3 would adversely affect dissolved oxygen through the Central and Elephant Butte-Caballo sections, although adaptive flexibility would mitigate this impact. Increasing the volume of water to downstream gages would assist in raising dissolved oxygen values within the affected sections for all alternatives. The adaptive flexibility measure would also assist in mitigating the impact Alternative B-3 has on water temperature in the Central and Elephant Butte-Caballo sections. Additional flowing water would assist in stabilizing water quality, abdicating against increased water temperatures in constricted channels or isolated pools.

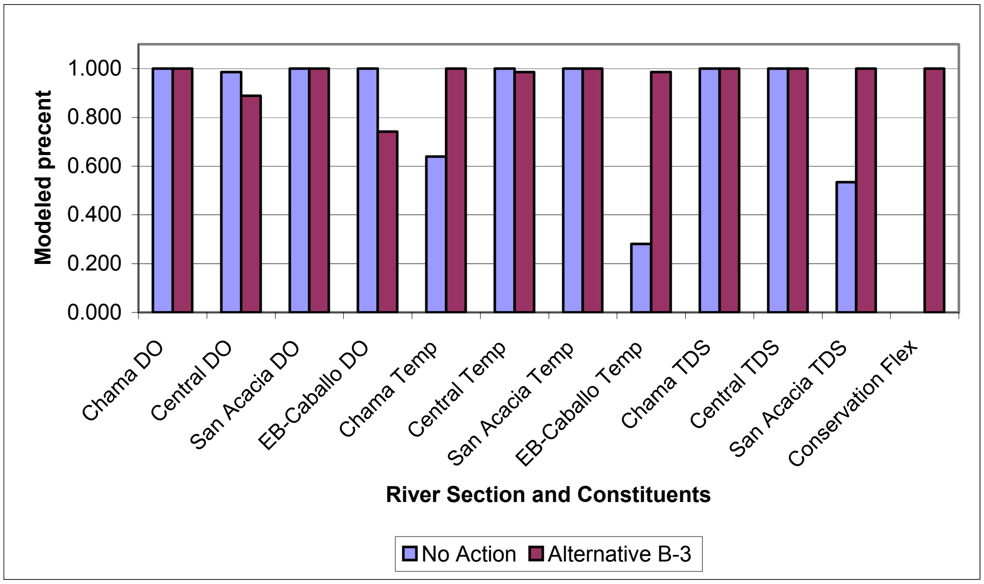

Figure M-5.5. A comparison of No Action and Alternative B-3 by constituent and river section.

5.10.1 Chama Section Supporting Figures

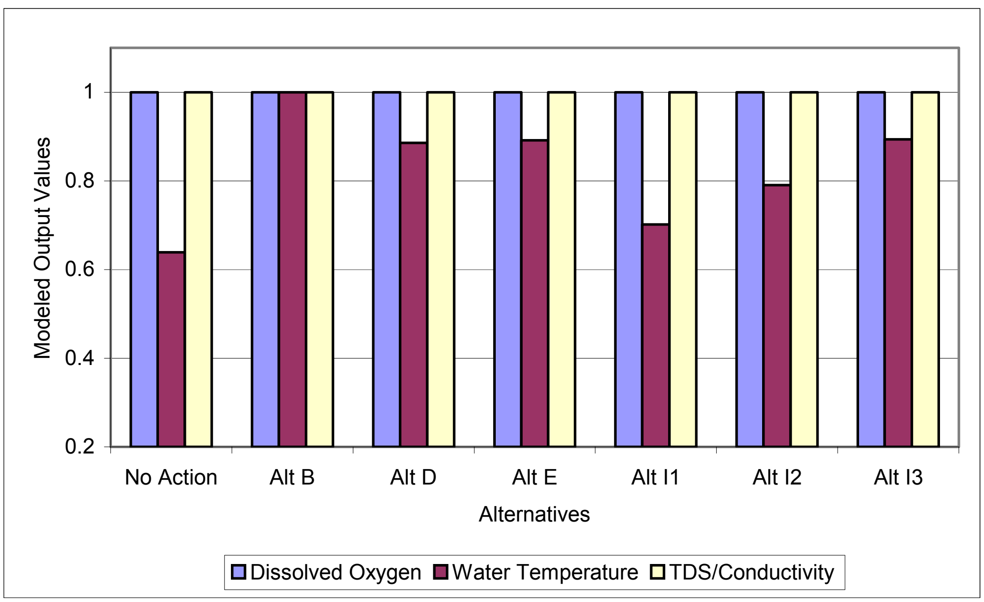

Figure M 5.6. Model output Chama Section water quality by alternative and constituent.

5.10.2 Central Section

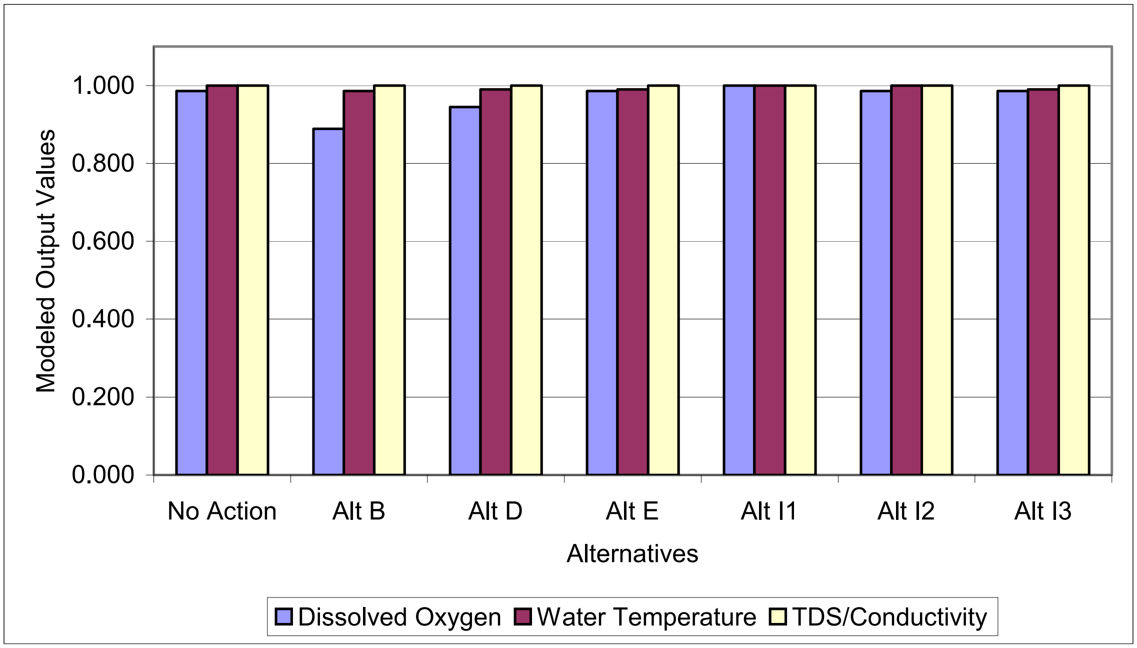

Figure M-5.7. Model output Chama Section water quality by alternative and constituent.

5.10.3 San Acacia Section

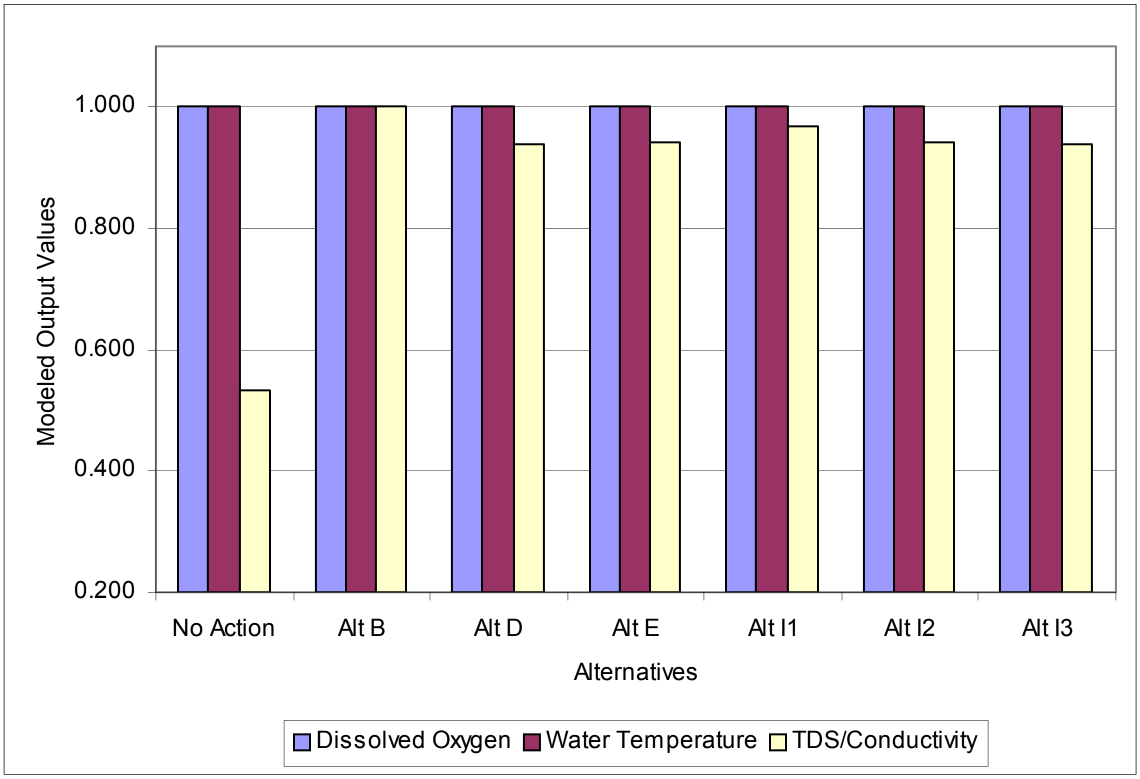

Figure M-5.8. Model output Chama Section water quality by alternative and constituent.

5.10.4 Elephant Butte-Caballo Section

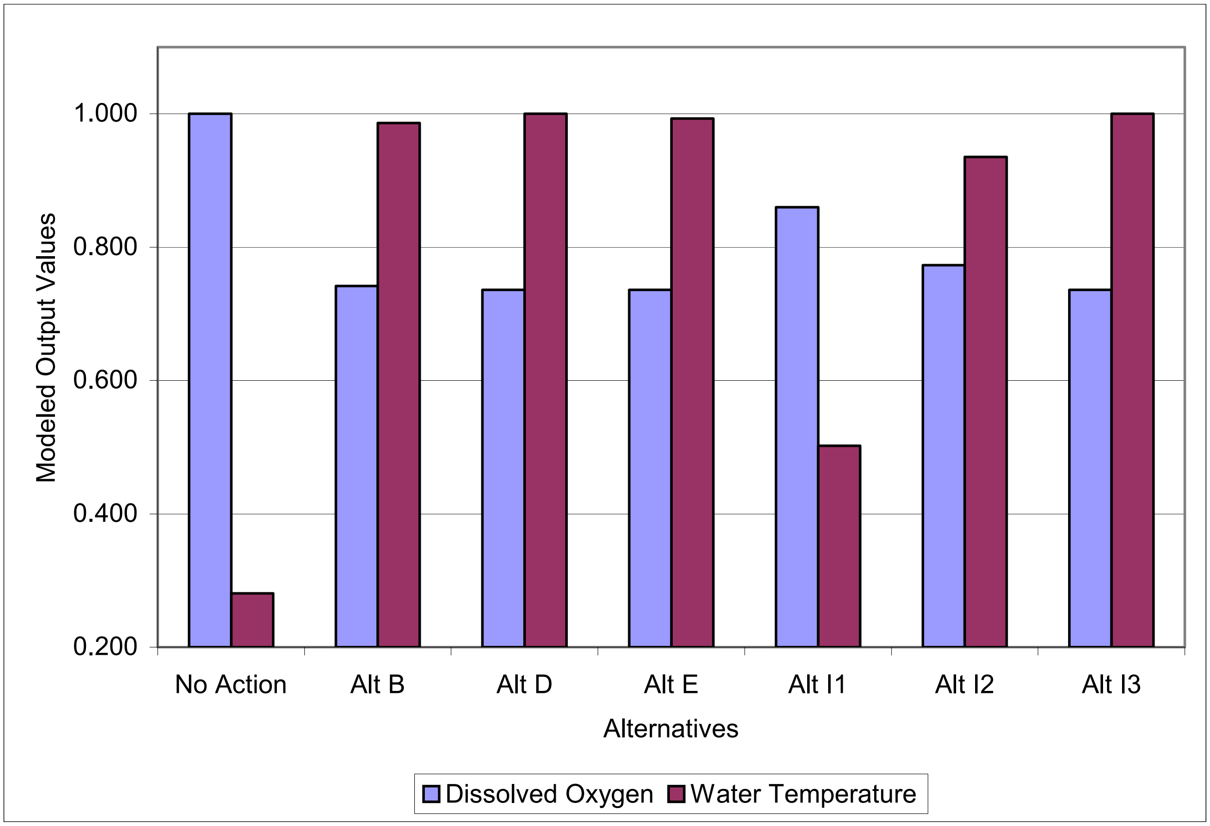

Figure M-5.9. Model output Chama Section water quality by alternative and constituent.

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6.0 Acronyms

BMP	Best Management Practices
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EIS	Environmental Impact Statement
ESI	Environmental Systems Research Institute
GIS	Geographic Information System
IBWC	International Boundary Water Commission
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephalometric Turbidity Unit
NWS	National Weather Service
TDS	Total Dissolved Solids
URGWOPS	Upper Rio Grande Water Operations
USACE	US Army Corps of Engineers
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
WQ	Water Quality
WQR	Water Quality Reach
WQRT	Water Quality Resource Team

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1.0 AGRICULTURE—LAND USE

Within the upper Rio Grande basin, most of the agricultural acreage falls within a 5-km buffer on either side of two major rivers, the Rio Grande and Rio Chama. This buffer comprises a total of 2,811,370 acres, of which about 7 percent overall is devoted to agriculture (**Table N-1.1**). The Southern section of the project area has the highest percent of its land devoted to agriculture (13 percent); the Rio Chama and San Acacia sections have the least (2 percent each). Agricultural acreage includes irrigated and non-irrigated land, field crops, planted and native grass pastures, orchards, vineyards, and fallow fields in rotation. Irrigation is accomplished by using either surface water directed from the rivers or ground water pumped up from wells.

Table N-1.1 Agricultural Acreage in the 5-km Buffer

River Section	Reach No.	Reach Acreage	Agriculture Acreage/ Reach	% Agricultural/ Reach
Northern	1	158,990	7,111	4%
	2	284,563	39,718	14%
	3	271,016	833	0%
	4	38,664	1,657	4%
	Subtotal	753,233	49,319	7%
Rio Chama	5	76,914	2,815	4%
	6	179,061	82	0%
	7	105,231	2,158	2%
	8	52,847	2,716	5%
	9	97,109	26	0%
	Subtotal	511,162	7,797	2%
Central	10	117,623	4,344	4%
	11	37,060	0	0%
	12	133,423	7,436	6%
	13	161,072	22,666	14%
	Subtotal	449,926	34,446	8%
San Acacia	14	439,926	10,441	2%
	Subtotal	439,926	10,441	2%
Southern	15	102,247	665	1%
	16	399,810	46,665	12%
	17	155,814	35,196	23%
	Subtotal	657,871	82,526	13%
	Total	**2,811,370**	**184,529**	**7%**

Source: USGS and EPA 2000

1.1 Irrigated Agriculture Crop Types

1.1.1 Northern Section

The Northern section includes portions of the Rio Grande in Colorado and in New Mexico. Within the 5-km buffer along the Rio Grande, the Northern section of the river comprises 753,233 acres, of which about 7 percent is agricultural (**Table N-1.1**). The region of the Northern section in Colorado includes Reach 1 (Rio Grande from Alamosa to the Colorado-New Mexico border) and Reach 2 (Conejos River from Platoro Reservoir to the Rio Grande confluence).

Up to 98,000 acres in this region are agricultural lands that have access to irrigation water from the two rivers (Vandiver 2003). This acreage includes a significantly larger area than is designated by the 5-km buffer. The number of acres that is actually irrigated in this region varies dramatically from year to year depending on the size of the water year and the extent of snow pack. Most of Reach 1 runs through two large ranches and the Alamosa National Wildlife Refuge, where 8,000 acres of native pasture are irrigated. The remaining irrigated acreage lies within Reach 2, and is devoted to alfalfa, small grains, potatoes and native grasses.

In the New Mexico portion of the Northern section (Reaches 3 and 4), about 70 percent of the agricultural land is devoted to forage; about 6 percent is divided between small grains and fruits and vegetables (**Table N-1.2**). The rest (23 percent) is left fallow. Reach 3 (Rio Grande from the Colorado-New Mexico border to Velarde) runs through the Carson National Forest and through the Taos and Picuris pueblos. The negligible amount of agricultural land (less than 0.5 percent) recorded along this reach falls in the pueblo lands. The majority of Reach 3 flows through Taos County. In Taos County, forage crops account for most (70 percent) of the irrigated lands (**Table N-1-3**). Almost half of the forage crop acreage is planted in alfalfa; the rest is divided between planted pastures and native pastures.

Table N-1.2 Percent crop type acreage for river sections in New Mexico

Crop type	Northern	Rio Chama	Central	San Acacia	Southern
small grains	3%	2%	3%	8%	3%
corn	0%	3%	5%	3%	3%
forage	70%	65%	52%	76%	23%
fruit/veg	3%	4%	8%	4%	14%
orchard	1%	2%	1%	0%	17%
cotton	0%	0%	0%	0%	26%
fallow	23%	24%	31%	9%	14%

Source: Derived from Lansford et al. 1993a, b; 1996

Notes: Data averaged from 1991 through 1995.
Crop types are categorized as follows:
Grains—wheat, barley, sorghum grown for grain, unspecified small grains.
Forage—alfalfa, other hays, planted pasture, native pasture.
Fruits/vegetables—potatoes, vineyards, melons, beans, peanuts, other field crops, lettuce.
Tree Crops— fruit and nut orchards.
Other—idle and fallow irrigated cropland.

Table N-1.3 Percent Crop Type in Counties of Northern and Rio Chama sections

Crop Type	Taos	Rio Arriba	Santa Fe
	%	%	%
Grains	4%	1%	5%
Corn	0%	0%	23%
Forage	70%	71%	46%
Fruits/Vegetables	3%	3%	7%
Tree Crops	0%	2%	2%
Cotton	0%	0%	0%
Other	22%	23%	17%
Total	**100%**	**100%**	**100%**

Source: Lansford et al. 1993a,b; 1996
Note: Data averaged over the years 1991-1995
Crop Types are categorized as follows:
Grains—wheat, barley, sorghum grown for grain, other small grains (unspecified).
Forage—alfalfa, other hays, planted pasture, native pasture.
Fruits/Vegetables—potatoes, beans, peanuts, other field crops, lettuce.
Tree Crops—fruit orchards.
Other—idle and fallow irrigated cropland

Reach 4 (Rio Grande from Velarde to the Rio Chama confluence), which runs through San Juan Pueblo, Española, and the small communities immediately north of Española, contains a somewhat higher proportion of agricultural lands (4 percent) (**Table N-1.1**). This entire reach falls within Rio Arriba County, in which forage crops account for most (71 percent) of the irrigated lands (**Table N-1.3**). Almost 75 percent of the forage crop acreage is in planted pastures; the rest is divided between alfalfa and native pasture.

1.1.2 Rio Chama Section

Within the 5-km buffer along the Rio Grande, the Rio Chama section of the river (Reaches 5 through 9) comprises 511,162 acres, of which relatively little (2 percent) is agricultural (**Table N-1.1**). The percentages of crop types in this section are similar to those in the Northern section (**Table N-1.2**). Approximately 65 percent of the agricultural lands are devoted to forage (predominantly alfalfa); about 11 percent divided between small grains, and fruits and vegetables. The rest (about 24 percent) is left fallow.

Reaches 5, 6, and 7 lie along the Rio Chama. Little is known about agricultural land along Reach 5 (from Heron Reservoir to El Vado); most of this reach runs through Heron Lake and El Vado Lake state parks (Wells 2003),

Along Reach 6 (from El Vado to Abiquiu reservoir), there are approximately 100 acres of land with access to irrigation by the Rio Chama. The U.S. Forest Service (USFS) has most of this acreage in irrigated rangeland pasture. A small amount of the irrigated acreage belongs to a monastery that has a vegetable garden (Wells 2003). This information corresponds with the statistics for Rio Arriba County described above (**Table N-1.3**), which is the county through which Rio Chama runs.

Reach 7 (Rio Chama from Abiquiu Reservoir to the Rio Grande confluence) runs through San Juan Pueblo and the small communities to northwest of Española. There are approximately 5,250 irrigated acres (Newville 2003), of which 94 percent is planted in alfalfa and pasture (Wells 2003). The remaining irrigated acreage is devoted to family orchards and a few small organic gardening ventures. This information corresponds with the statistics for Rio Arriba County, through which the entire Rio Chama runs (**Table N-1.3**).

Reach 8 (Rio Grande from the Rio Chama confluence to the Otowi gage) runs through the alluvium of the Española Valley. Here, the San Juan, Santa Clara, Pojoaque, and San Ildefonso pueblos, along with the communities immediately south of Española, contribute to a somewhat higher degree of agriculture (5 percent). The major portion of Reach 8 runs through Santa Fe County, in which nearly half of the agricultural acreage is devoted to forage crops (mostly alfalfa) and a significant portion (23 percent) to corn (**Table N-1.3**). The remaining acreage is divided between small grains (mostly wheat), fruits and vegetables, and orchards.

Reach 9 (Rio Grande from Otowi gage to Cochiti Dam) runs through Santa Fe National Forest and Bandelier National Monument, which is why there is almost no land along this reach that is considered agricultural (**Table N-1.1**).

1.1.3 Central Section

The Central section of the project area begins at Cochiti Dam and ends at Elephant Butte Reservoir. This region includes Reaches 10 through 13. The Central section includes a number of tribal lands (Cochiti, San Felipe, Santa Ana, Santa Domingo, Zia, Sandia, and Isleta Pueblos), as well as the cities of Albuquerque, Belen, and Socorro, which may account for the somewhat higher level of agricultural land use. Within the 5-km buffer along the Rio Grande, the Central section comprises about 449,178 acres, of which about 8 percent is agricultural (**Table N-1.1**). In general, from the Northern to the Central section, there is a steady decrease in land devoted to pasture forage and an increase in land planted in crops (**Table N-1.2**). Approximately 52 percent of the irrigated farmland is devoted to forage; about 17 percent is planted in grains, fruits and vegetables. The rest (about 31 percent) is left fallow.

All of Reach 10 falls within Sandoval County, in which 59 percent of the irrigated agricultural lands are devoted to forage crops (mostly planted pasture) (**Table N-1.4**). A small portion of the agricultural lands (7 percent) is devoted to fruits and vegetables, and 24 percent is irrigated idle or fallow land. The rest is divided between small grains, corn, and orchards. Reach 11 (the small portion of the Jemez river between Jemez Dam and the Rio Grande confluence) is assumed to fall within the 5-km buffer along Reach 10 and therefore to be included in the data presented for Reach 10.

Table N-1.4 Percent Crop Type for Counties in Central Section

Crop Type	Sandoval	Bernalillo	Valencia
	%	%	%
Grains	1%	1%	7%
Corn	2%	9%	6%
Forage	40%	64%	53%
Fruits/Vegetables	9%	11%	6%
Tree Crops	2%	1%	0%
Cotton	0%	0%	0%
Other	45%	15%	28%
Total	**100%**	**100%**	**100%**

Source: Lansford et al. 1993a,b; 1996.
Note: Data averaged over the years 1991-1995.
Crop Types are categorized as follows:
Grains—wheat, barley, sorghum grown for grain, other small grains
Forage—alfalfa, sorghum, planted pasture, native pasture.
Fruits/Vegetables—beans, vineyards, chilies, other field crops lettuce.
Tree Crops—fruit orchards
Other—idle and fallow irrigated cropland

Most of Reach 12 falls within Bernalillo County, in which 64 percent of the agricultural lands is devoted to forage crops (two-thirds of which is alfalfa; the rest is planted pasture) (**Table N-1.4**). Approximately 15 percent is idle or fallow irrigated land. The remaining irrigated acreage is divided between corn, and fruits and vegetables, with a very small amount of land planted in small grains and orchards.

Most of Reach 13 falls within Valencia County, in which half (53 percent) of the irrigated agricultural lands is devoted to forage crops (mostly alfalfa and planted pasture) (**Table N-1.4**) and 28 percent is idle or fallow. The rest of the irrigated acreage is divided, for the most part, between small grains, corn, and fruits and vegetables.

1.1.4 San Acacia Section

The San Acacia section of the river flows near the La Joya Wetland Game Refuge, the Sevilleta and Bosque del Apache National Wildlife Refuges, and Elephant Butte State Park, which may account for the somewhat lower levels of agricultural land use in this section. Within the 5-km buffer along the Rio Grande, the San Acacia section (Reach 14) comprises approximately 439,926 acres, of which about 2 percent is agricultural (**Table N-1.1**). Overall, there is an increase in acreage devoted to pasture and a decrease in the amount of acreage left fallow. Approximately 76 percent of the agricultural acreage is devoted to pasture; about 15 percent is planted in small grains, fruits and vegetables (**Table N-1.2**). Only about 9 percent is left fallow. Most of Reach 14 falls within Socorro County, in which 77 percent of the irrigated agricultural land is devoted to forage (mostly alfalfa) and only 8 percent is idle or fallow. The rest is divided between small grains, corn, and fruits and vegetables (**Table N-1.5**).

1.1.5 Southern Section

The Southern section includes lands along the Rio Grande from Elephant Butte Reservoir in New Mexico to American Dam at El Paso near the New Mexico-Texas border to Fort Quitman in Texas. This region includes Reaches 15, 16, and 17.

Within the 5-km buffer along the Rio Grande, the Southern section comprises approximately 657,871 acres, of which about 12.5 percent are agricultural (**Table N-1.1**), the highest level of agricultural land use in the project area. Overall, fallow land decreases and land devoted to field crops (most notably cotton) and orchards increases in the Southern section (**Table N-1.2**). Acreage devoted to forage pasture decreases to a low of 23 percent, about the same amount as is planted in cotton (26 percent). Land planted in fruits and vegetables and fallow land are all about 15 percent of the total agricultural acreage.

All of Reach 15 is in Sierra County, in which most of the irrigated agricultural land is devoted either to forage crops (31 percent) or to fruits and vegetables (27 percent). Small grains and corn each account for over 10 percent of the irrigated acreage. The remaining 4 percent is divided between tree crops and cotton (**Table N-1.5**).

Table N.1-5 Percent Crop Type for Counties in San Acacia and Southern sections

Crop Type	Socorro	Sierra	Doña Ana
	%	%	%
Grains	8%	7%	4%
Corn	3%	5%	5%
Forage	77%	31%	16%
Fruits/Vegetables	3%	27%	16%
Tree Crops	0%	3%	18%
Cotton	0%	1%	21%
Other	8%	25%	20%
Total	**100 %**	**100 %**	**100 %**

Source: Lansford et al. 1993a,b; 1996.
Note: Data averaged over the years 1991-1995
Crop Types are categorized as follows:
Grains—wheat, unspecified small grains.
Forage—alfalfa, sorghum, planted pasture, native pasture.
Fruits/Vegetables—beans, vineyards, chilies, lettuce, other field crops.
Tree Crops—fruit and nut orchards.
Other—idle and fallow irrigated cropland.

Most of Reach 16 lies within Doña Ana County, where the irrigated acreage is more or less evenly divided between forage crops, fruits and vegetables, pecans, cotton, and fallow or idle lands (**Table N-1.5**). Less than 10 percent is divided between small grains and corn. The total land irrigated in the two counties in the southern region is estimated at 109,934 acres.

All of Reach 17 lies within Texas between El Paso and Fort Quitman. There are 155,814 acres within the 5-km buffer, of which 23 percent is considered agricultural (**Table N-1.1**). According to U.S. Bureau of Reclamation (Reclamation) data (2001), there are 49,396 agricultural acres irrigated per year in this region (**Table N-1.6**). Nearly 50 percent of this land is used for growing cotton. Almost 25 percent is planted in pecans and another 25 percent in forage. The small amount of remaining acreage (less than 3 percent) is planted in fruits and vegetables and in family gardens and orchards.

Table N-1.6 Texas Crop Acreage (For the Year 2001)

Crop Type	Acreage 2001	% of Total
Grains	0	0%
Corn	0	0%
Forage	12,298	25%
Fruits/Vegetables	1,226	2%
Nuts	11,484	23%
Cotton	24,277	49%
Other	111	0%
Total	**49,396**	**100%**

Source: Reclamation 2001
Note: Crops categorized as follows:
Forage—silage, alfalfa, other hay, pasture.
Fruits/Vegetables—onions, peppers, other miscellaneous field crops.
Tree Crops—pecans.
Other family gardens and orchards (*not* fallow or idle lands).

1.1.6 Irrigation Water Source

In general, when surface water is available from the Rio Grande or one of its tributaries, this is the source of water used for irrigating agricultural lands. Some lands have access only to surface water. Some lands have access to both ground water (through private wells) and to surface water. The lands that use a combination of sources only use the wells in years when the surface water is insufficient. A smaller portion of lands use ground water exclusively.

1.1.7 Colorado

All water used for agricultural irrigation in the Closed Basin region of the Project Area is surface water delivered from the Rio Grande and Rio Conejos by irrigation ditches.

1.1.8 New Mexico

The overall trend indicates that irrigation in the northern part of the state relies most heavily on surface water, whereas farther south, ground water becomes increasingly important. More specifically, in the counties of northern New Mexico, most (81 percent) of the irrigated acreage is served by surface water only. A substantial portion (17 percent) is served by ground water only (**Table N-1.7**). A negligible portion (2 percent) is served by surface water that is supplemented by well water as needed.

In the counties of central New Mexico, the acreage irrigated by only surface water decreases (to 59 percent), while the acreage served by surface water that is supplemented by well water increases (to 39 percent). Only 2 percent is served by ground water only. This practice contrasts with the counties in southern New Mexico, where negligible acreage is served by surface water only (3 percent). Most of the land is served by surface water that is supplemented by well water as needed (86 percent); 11 percent is served by ground water only.

1.1.9 Texas

All irrigation of agricultural lands in Texas from El Paso to Fort Quitman has involved the use of surface water for a number of years (Grajeda 2003). However, due to the short supply of water in 2003, ground water may be used during following growing seasons.

Table N-1.7 Acreage of Land Irrigated by Surface Water Only or Ground Water Only or a Combination of Surface Plus Ground Water

County	Reach No.	Acreage	% Surface	% Ground	% Combination
Taos	3	41,900	86%	12%	2%
Rio Arriba	4,5,6,7	41,110	98%	1%	1%
Santa Fe	8	18,070	32%	63%	5%
Northern New Mexico		101,080	81%	17%	2%
Sandoval	9,10	17,270	95%	0%	5%
Bernalillo	12	10,630	64%	3%	33%
Valencia	13	28,542	66%	0%	34%
Socorro	14	21,240	16%	6%	78%
Central New Mexico		77,682	59%	2%	39%
Sierra	15	11,400	27%	26%	47%
Doña Ana	16	96,030	0%	10%	90%
Southern New Mexico		107,430	3%	11%	86%

Source: Lansford et al. 1993a, 1993b, 1996
Notes: Data averaged over the years 1991–1995.
Reach No. refers to associated reach and is not an exact match with the reaches.

1.2 Dry Cropping

1.2.1 Colorado

No information is available concerning dry cropping in Colorado.

1.2.2 New Mexico

The overall trend indicates that dry cropping is practiced more in the northern regions of New Mexico where there is more rain and the summers are cooler. Dry cropping is practiced less the farther south the farmland is located.

Dry cropping accounts for 9 percent to 13 percent of the agricultural acreage in the counties of northern New Mexico (**Table N-1.8**). In three of the central counties, dry cropping accounts for less than 9 percent of the total farmland cultivated. In one central county (Bernalillo) dry cropping is practiced on 45 percent of the land. No dry cropping is practiced in the southern counties of New Mexico.

According to one review, there is a historical trend as well (SSPA 2002). Approximately 30 percent of agricultural lands in the MRGCD were dry cropped prior to and during the 1970s. This average shifted to the current levels of dry cropping in the 1980s.

Table N-1.8 Dry Crops (Percent Farmland Acreage Irrigated and Dry Cropped in New Mexico Data Averaged Over the Years 1991–1998)

County/Region	Associated Reach No.	Total Acres Farmed	% Irrigated	% Dry Cropped
Taos	3	47,900	87%	13%
Rio Arriba	4,5,6,7	45,110	91%	9%
Santa Fe	8	20,100	90%	10%
Northern New Mexico		113,110	89%	11%
Sandoval	9,10	19,070	91%	9%
Bernalillo	12	11,630	91%	9%
Valencia	13	28,542	100%	0%
Socorro	14	38,740	55%	45%
Central New Mexico		97,982	79%	21%
Sierra	15	11,400	100%	0%
Doña Ana	16	96,030	100%	0%
Southern New Mexico		107,430	100%	100%

Source: Lansford et al. 1996; USDA 1997, 1998
Note: Irrigated farmland includes idle and fallow land that is irrigated.

1.2.3 Texas

Approximately 15 percent of the agricultural acreage in Texas is dry cropped (Reclamation 2001).

1.3 Impact Analysis

The review for agricultural resources evaluates whether operational actions could change conditions needed to support the type, extent, and quantity of agriculture currently practiced within the Upper Rio Grande Basin. Drought and population growth have had incremental impacts on land use, crop types, and harvest levels over time and will continue to do so. This analysis is primarily concerned with identifying distinguishable differences between the alternatives for key issues that directly affect agriculture in the Basin. These include:

- Impacts to delivery of water to irrigators and growers (Central and San Acacia sections);
- Impacts to acequia diversion structures (Rio Chama section);
- Loss of viable agricultural land and crops through inundation;
- Loss of or reduced productivity of agricultural lands due to saturated soil conditions (Rio Chama).

The analysis relies on summarized outputs from URGWOM and FLO2D to make broad comparisons using the following measurable criteria:

- Average seasonal shortfall in meeting irrigator water requests; number of years with shortfalls; number of days with shortfalls;
- Number of days when diversion elevation are exceeded by river elevation;
- Extent and duration of inundated agricultural land (Reach 7, 8, 9, 12, 13, 14);
- Frequency of prolonged "bank full" flows (Reach 7).

1.3.1 Assumptions and Limitations

The review is limited to operations that may affect about 53,000 acres of agricultural land along the Rio Chama, Central and San Acacia sections. This represents less than 30 percent of the agricultural land in the Upper Rio Grande basin. Other sections and reaches that are outside the influence of operations within the authority of this review and decision are not further evaluated, including the Northern section, Reach 5 in the Rio Chama section, Reach 11 in the Central section, and the Southern section.

- The demand schedule for irrigators below Cochiti is assumed to be the same as current demands over the next 40-years;
- Several existing agreements will ensure meeting water needs to irrigators along the Rio Chama, and therefore issues revolve around performance of the diversion structures, soil saturation, and inundation.

Tables N-1.8 through **N-1.15** provide data analyses for key criteria that may affect agriculture associated with the Upper Rio Grande surface water system. These criteria are indicative (and not all-inclusive) of river-related factors that affect growers, and illustrate the relative difference between the alternatives in responding to agricultural needs.

Table N-1.8 provides aggregated data on deliveries to four diversions that supply irrigators in the Middle Rio Grande Basin. **Table N-1.9** summarizes the average annual seasonal shortfall in deliveries to irrigators in the Central and San Acacia sections over the 40-year project life. The shortfall would be almost 32 percent under No Action. Shortfalls to specific diversions vary greatly, with Cochiti receiving most of its requested demand and Isleta experiencing significant shortfalls from requested demand. **Table N-1.10** reflects the same pattern in the variation between the number of years and percentage of delivery days where shortfalls are estimated over the project life. Complex agreements between the State of New Mexico and the City of Albuquerque allow irrigation water demands of growers along the Rio Chama to be maintained (Gallegos 2004). Overall, the No Action performs slightly better on average than the other alternatives in meeting delivery requests, but the advantage is minimal, with some localized variations.

Table N-1.9 Delivery Shortfalls-Aggregated Data from URGWOM Alternatives Model for four diversions

Average Shortfall per Day

Diversion	B	No Action	D	E	I-1	I-2	I-3
Cochiti	-24.58	-24.60	-33.61	-24.18	-23.92	-25.96	-32.89
Isleta	-368.59	-369.09	-368.02	-367.73	-369.13	-369.20	-368.46
San Acacia	-53.40	-53.70	-53.34	-53.72	-53.79	-53.73	-53.72
San Felipe	-134.99	-139.31	-137.80	-137.93	-137.87	-138.53	-138.90

Average Number of Days of Shortfall During years of Shortfall

Diversion	B	No Action	D	E	I-1	I-2	I-3
Cochiti	22.25	21.20	20.60	24.00	25.25	20.00	20.40
Isleta	137.90	136.60	139.53	138.93	137.68	138.63	139.28
San Acacia	49.41	48.78	49.81	49.57	49.03	49.73	49.86
San Felipe	53.96	49.80	47.81	49.72	50.48	48.31	48.08

Number of Years of Shortfall

Diversion	B	No Action	D	E	I-1	I-2	I-3
Cochiti	4	5	5	4	4	5	5
Isleta	40	40	40	40	40	40	40
San Acacia	37	37	37	37	37	37	37
San Felipe	23	25	26	25	25	26	26

Average Annual Seasonal Request

Diversion	B	No Action	D	E	I-1	I-2	I-3
Cochiti	196.40	196.40	196.40	196.40	196.40	196.40	196.40
Isleta	494.23	494.23	494.23	494.23	494.23	494.23	494.23
San Acacia	103.82	103.44	104.12	103.95	103.66	103.92	104.07
San Felipe	229.93	229.93	229.93	229.93	229.93	229.93	229.93

Average Annual Request

Diversion	B	No Action	D	E	I-1	I-2	I-3
Cochiti	140.34	140.34	140.34	140.34	140.34	140.34	140.34
Isleta	332.87	332.87	332.87	332.87	332.87	332.87	332.87
San Acacia	66.16	66.05	66.55	66.39	66.13	66.37	66.50
San Felipe	186.00	186.00	186.00	186.00	186.00	186.00	186.00

Average Seasonal Shortfall

Diversion	B	No Action	D	E	I-1	I-2	I-3
Cochiti	-0.21	-0.25	-0.33	-0.22	-0.23	-0.25	-0.32
Isleta	-206.62	-204.95	-208.73	-207.67	-206.59	-208.05	-208.61
San Acacia	-10.35	-10.26	-10.40	-10.43	-10.33	-10.46	-10.48
San Felipe	-14.00	-14.49	-14.31	-14.32	-14.54	-14.54	-14.50

Average Annual Demand (Diversion)

Diversion	B	No Action	D	E	I-1	I-2	I-3
Cochiti	140.19	140.16	140.11	140.18	140.18	140.16	140.11
Isleta	193.71	194.83	192.29	193.00	193.73	192.74	192.37
San Acacia	60.35	60.26	60.65	60.49	60.31	60.45	60.55
San Felipe	174.54	174.13	174.28	174.27	174.09	174.09	174.12

Average Annual Seasonal Demand (Diversion)

Diversion	B	No Action	D	E	I-1	I-2	I-3
Cochiti	196.19	196.15	196.07	196.18	196.17	196.15	196.08
Isleta	287.61	289.28	285.50	286.56	287.64	286.18	285.62
San Acacia	93.47	93.18	93.72	93.52	93.32	93.46	93.58
San Felipe	215.94	215.44	215.62	215.61	215.40	215.40	215.43

Days of Shortfall over a 40 year period

Diversion	B	No Action	D	E	I-1	I-2	I-3
Cochiti	89	106	103	96	101	100	102
Isleta	5516	5,464	5,581	5,557	5,507	5,545	5,571
San Acacia	1828	1,805	1,843	1,834	1,814	1,840	1,845
San Felipe	1241	1,245	1,243	1,243	1,262	1,256	1,250

Table N-1.10 Average Annual Seasonal Shortfall to Irrigators over 40 years (Central and San Acacia Sections)

Alternative	Av. Annual seasonal shortfall (%)	Cochiti diversion[1]	Isleta diversion[1]	San Acacia diversion[2]	San Felipe diversion[2]
No Action	31.7	0.2	61.6	15.5	7.8
B-3	31.9	0.1	62.1	15.7	7.5
D-3	32.2	0.2	62.7	15.7	7.7
E-3	32.1	0.2	62.4	15.8	7.7
I-1	31.9	0.2	62.1	15.6	7.8
I-2	32.2	0.2	62.5	15.8	7.8
I-3	32.3	0.2	62.7	15.9	7.8

Notes:

1. Central section
2. San Acacia section

Best

Worst

Table N-1.11 Shortfalls in Delivery of Water to Irrigators over 40 years (Central and San Acacia Sections)

Alternative	No. of years with shortfall				Number/% days with shortfall			
	A	B	C	D	A	B	C	D
No Action	5	40	37	25	106/1	5,464/56	1,805/18	1,245/10
B-3	4	40	37	23	89/1	5,516/56	1,828/19	1,241/10
D-3	5	40	37	26	103/1	5,581/57	1,843/19	1,243/10
E-3	4	40	37	25	96/1	5,557/57	1,834/19	1,243/10
I-1	4	40	37	25	101/1	5,507/56	1,814/19	1,262/11
I-2	5	40	37	26	100/1	5,545/57	1,840/19	1,256/11
I-3	5	40	37	26	102/1	5,571/57	1,845/19	1,250/10

Notes:

1. Cochiti diversion (Central section)
2. Isleta diversion (Central section)
3. San Acacia diversion (San Acacia section)
4. San Felipe diversion (San Acacia section)

Best

Worst

Inundation is another key criteria evaluated since crops may be damaged or destroyed by flooding, depending on the time and duration of the event. Output from FLO2D provides the extent, location, and duration of inundation over the project life for the Rio Chama, Central and San Acacia sections. This geospatial information of the extent of inundation was also examined in combination with aerial photography in order to discern land cover and use of inundated areas. **Table N-1.11** provides the aggregated data from FLO2D modeling outputs for inundation by reach. **Table N-1.12** summarizes acre/days of inundation by section estimated for the 40-year project period for the alternatives. Inundation of agricultural land is very localized, and is mostly concentrated at a few locations along the Rio Chama below Abiquiu. The No Action performs reasonable well in limiting inundation and potential impact on agriculture. The extent of inundation of agricultural land on tribal and pueblo areas is not calculated. Based on an examination of inundated areas, agricultural land would overall be least affected under the No Action on the Rio Chama. Based on information of all lands inundated, Alternative b performs fairly well for both the Rio Chama and Central section. Model outputs show no inundation on agricultural land below Bernalillo (i.e., Reaches 12, 13, and 14) under any alternative.

Table N-1.12 Inundation of Agricultural Lands

Alternative	Total inundation (acre-days)[1]			Inundated agricultural land (acre-days)[1]		
	Rio Chama section	Central section	San Acacia section	Rio Chama section[2]	Central section[3]	San Acacia section
No Action	58,173	442,721	2,832,820	9,496	0	0
B-3	61,730	399,937	1,180,849	11,340	0	0
D-3	142,153	493,045	532,531	23,547	0	0
E-3	109,085	442,045	592,805	19,279	0	0
I-1	163,010	509,956	518,686	28,279	0	0
I-2	133,150	478,655	2,332,710	23,529	0	0
I-3	112,595	430,853	2,136,233	19,933	0	0

Notes:

1. It is assumed for this analysis that areas outside levees would not be inundated.
2. Totals do not include agricultural land in tribal areas in Reach 9.
3. Some portion of inundated land in reach 10 in the Central section, mostly in tribal and pueblo land, may be agricultural, but the quantity is unknown. No agricultural land in the reaches 12 or 13 in the Central section is inundated.

Best
Worst

Diversion structures along the Rio Chama are frequently washed out and some level of seasonal maintenance and repairs after high flow events is normal. While overtopping diversions does not necessarily result in damage, this criterion is indicative of which alternatives may be more maintenance intensive than others. **Table N-1.13** shows the number of times any diversion on the Rio Chama is overtopped at least once in the runoff season over 40 years. Under the No Action, this occurs 219 times out of a total of 520 possible occurrences over 40 years. The No Action represents a continuation of the historic pattern and frequency of events and conditions that require maintenance of diversion structures, and possible interruptions in delivery of irrigation water along acequias.

Table N-1.13 Overtopping Events of Diversions along the Rio Chama – 40-year Estimate

Alternative	No. of years with one diversion overtopped	Number of overtopping events[1]	Difference from No Action (%)
No Action	38	219	-
B-3	35	174	21
D-3	34	199	9
E-3	36	210	4
I-1	38	225	-3
I-2	36	214	2
I-3	36	210	4

Source: FLO2D, Reach 7, maximum elevation; diversion grid cells

Notes:

1. Sum of annual tally of diversions overtopped at least once in any given year.

Best
Worst

Saturated soils along the Rio Chama (below Abiquiu) is an ongoing concern for crops planted adjacent to the river. Saturated soils are unsuitable for roots for most crops and can inhibit seed germination. In addition, growers may be unable to “work” saturated soils. These conditions result when the river runs at “bank full” for extended periods. **Table N-1.14** provides aggregated data derived from URGWOM outputs for this criterion. To compare the potential for this problem to occur, **Table N-1.15** shows the number of events when discharges out of Abiquiu are 1,500 cubic feet per second (cfs) or greater for durations of 7 days or more over the 40-year project period. Under the No Action, this situation may result 33 times over the next 40-years during the spring and summer run-off season. The No Action performs least favorably of the alternatives on these criteria. (Other events may occur because of precipitation outside the modeled spring and summer runoff season.) Alternative B-3 provides the most favorable conditions for Reach 7 with the least potential for bank full conditions.

Table N-1.14 Bankfull Conditions Reach 7

times flows exceed 1500 cfs for more than 7 days by alternative

Alternative	Total # times	Total # times during growing season
Alt B	0	0
Alt D	24	20
Alt E	24	19
Alt I-1	32	32
Alt I-2	27	27
Alt I-3	24	19
No Action	33	33

Total # days when flows exceed 1500 cfs

Alternative	Total # days	Total # days during growing season
Alt B	3	0
Alt D	852	741
Alt E	895	773
Alt I-1	1,214	1,213
Alt I-2	989	989
Alt I-3	903	780
No Action	1,255	1,253

Table N-1.15 Extended Bank Full Events over 40-years in Reach 7

Alternative	Number of bank full events
No Action	33
B-3	0
D-3	20
E-3	19
I-1	32
I-2	27
I-3	19
Average	21

Source: URGWOM, 40 year daily flows at gauge below Abiquiu
Best
Worst

Agriculture is one of the uses of pueblo and tribal land along the river. Delivery of irrigation water to tribes and pueblos is provided for as one of the non-discretionary operational criteria and therefore would not vary between alternatives. Climate and weather can affect deliveries. However, impact of drought on deliveries to tribes is beyond the scope of this evaluation. Inundation can also affect crop production. The difference in impacts between the alternatives from inundation of agricultural lands on pueblos may be similar to the effects reported for all inundation in **Table N-1.12**. Based on this, inundation of agricultural lands on pueblos may be slightly less extensive under the No Action.

The No Action alternative would overall perform better than other alternatives evaluated for agriculture activity. Particularly, this alternative provides a minor benefit over the other alternatives for the large number of small-scale operations in the middle valley below Cochiti (including hobby farming, family subsistence farming, and local specialty and produce growers) because water deliveries may be somewhat more reliable.

1.3.2 Dry Cropping

Dry cropping may be affected both positively and negatively by inundation depending on the timing of the event. The San Acacia section has the highest percentage of dry crop farming (about 45 percent). This reach experiences the greatest variation between alternatives in potential inundation with No Action resulting in about 2.8 million acre/days of inundation over 40 years. This reflects no diversion to the LFCC under the No Action. Alternatives I-2 and I-3 also have relatively high inundation in the San Acacia section. Alternatives D, E and I-1 result in about 80 percent less inundation reflecting more diversion to the LFCC.

Dry pastures along the Rio Chama would have the highest potential for inundation under Alternative I-1 (17, 803 acre/days) and the least under the B-3 (with 783 acre/days).

1.3.3 Ground Water Use

Ground water use for irrigating may increase in dry years, and when irrigator requests are not met. This criterion can only be evaluated for Reaches 10 through 14 with the information available and the operating assumptions for reaches below Elephant Butte.

As shown in **Tables N-1.8** and **N-1.9**, there is little variation in the overall performance of the alternatives to meet irrigator demands. Therefore, over the 40-year period, water operations should have no appreciable influence on the portion irrigation water supplied through surface only, surface and ground, or ground-only sources. During drought years, under all alternatives, it is likely that ground water sources would supplement surface sources where possible.

Table N-1.16 Inundation by Reach – Aggregated Grid Cell Data (acre/days, acres)

Summary of all grid cells inundated by Alternative and Reach

Acre-Days total for 40 years

Alternative	Reach 7	Reach 8	Reach 9	RC section	Reach 10	Reach 12	Reach 13	Central Sec	Reach 14
NO ACTION	16,817	41,129	227	**58,173**	56,631	145,411	240,679	**442,721**	**2,832,820**
ALT B	4,770	56,557	376	**61,703**	49,141	132,072	218,724	**399,937**	**1,180,849**
ALT D	93,435	48,422	297	**142,153**	68,727	162,007	262,311	**493,045**	**532,531**
ALT E	64,407	44,412	266	**109,085**	52,842	146,034	243,169	**442,045**	**592,805**
ALT I-1	106,764	55,877	370	**163,010**	72,358	169,937	267,661	**509,956**	**518,686**
ALT I-2	82,544	50,304	302	**133,150**	63,435	155,526	259,694	**478,655**	**2,332,710**
ALT I-3	64,072	48,254	269	**112,595**	53,704	142,430	234,718	**430,853**	**2,136,233**
	432809	344955	2106	779,870	416,839	1,053,416	1,726,956	3197211	10126635

Total Acres Affected

Alternative	Reach 7	Reach 8	Reach 9	RC section	Reach 10	Reach 12	Reach 13	Central Sec	Reach 14
NO ACTION	1,384	2,364	34	**3,782**	1,911	4,821	8,494	**15,225.37**	**86,708**
ALT B	4,721	3,161	52	**7,934**	1,733	4,528	7,811	**14,071.85**	**43,274**
ALT D	4,681	2,553	34	**7,269**	3,735	8,907	14,308	**26,949.91**	**26,412**
ALT E	3,385	2,456	34	**5,875**	1,922	5,297	9,177	**16,396.14**	**23,422**
ALT I-1	4,736	3,132	52	**7,921**	4,395	9,590	14,979	**28,964.19**	**25,712**
ALT I-2	3,930	2,760	40	**6,730**	2,433	5,377	9,940	**17,750.47**	**81,371**
ALT I-3	3,300	2,519	34	**5,853**	1,957	4,930	8,896	**15,782.06**	**78,421**
	26,138	18,944	281	45,363	18,086	43,449	7,3604	135,140.00	365,320

Ag land Acre-Days total for 40 years

Alternative	Reach 7	Reach 8	Reach 9	RC section	Reach 10	Reach 12	Reach 13	Central Sec	Reach 14
NO ACTION	1,390	8,105.38	37.18	**9,533**	9,873	0	0	**9,873.053**	**0**
ALT B	783	10,557.22	69.56	**11,410**	8,567	0	0	**8,567.360**	**0**
ALT D	14,369	9,178.12	49.22	**23,596**	11,982	0	0	**11,981.930**	**0**
ALT E	10,700	8,579.15	47.11	**19,326**	9,213	0	0	**9,212.596**	**0**
ALT I-1	17,803	10,475.33	64.25	**28,343**	12,615	0	0	**12,615.010**	**0**
ALT I-2	13,859	9,669.96	53.56	**23,583**	11,059	0	0	**11,059.330**	**0**
ALT I-3	10,631	9,301.31	47.66	**19,980**	9,363	0	0	**93,62.825**	**0**
	69,537	65,866.00	369.00	135,772	72,672	0	0	72,672.000	0

Total Acres Ag Land Affected

	Reach 7	Reach 8	Reach 9	RC section	Reach 10	Reach 12	Reach 13	Central Sec	Reach 14
NO ACTION	126	470	6	**602**					
ALT B	691	614	10	**1,315**					
ALT D	673	511	6	**1,189**					
ALT E	507	493	6	**1,007**					
ALT I-1	694	597	9	**1,299**					
ALT I-2	591	522	7	**1,121**					
ALT I-3	488	499	6	**994**					
	3,771	3,706	49	7527					

Score for inundated agricultural land by reach

Alternative	Reach 7	Reach 8	Reach 9	RC section	Reach 10	Reach 12	Reach 13	Central Sec	Reach 14
NO ACTION	98.00%	87.69%	89.91%	**92.98%**	86.41%	**100%**	**100%**	**86.41%**	**100%**
ALT B	98.87%	83.97%	81.13%	**91.60%**	88.21%	**100%**	**100%**	**88.21%**	**100%**
ALT D	79.34%	86.07%	86.64%	**82.62%**	83.51%	**100%**	**100%**	**83.51%**	**100%**
ALT E	84.61%	86.97%	87.22%	**85.77%**	87.32%	**100%**	**100%**	**87.32%**	**100%**
ALT I-1	74.40%	84.10%	82.57%	**79.12%**	82.64%	**100%**	**100%**	**82.64%**	**100%**
ALT I-2	80.07%	85.32%	85.47%	**82.63%**	84.78%	**100%**	**100%**	**84.78%**	**100%**
ALT I-3	84.71%	85.88%	87.07%	**85.28%**	87.12%	**100%**	**100%**	**87.12%**	**100%**

Dev from average acres affected - all lands

	Reach 7	Reach 8	Reach 9	RC section	Reach 10	Reach 12	Reach 13	Central Sec	Reach 14
NO ACTION	1,384	2,364	34	**3,782**	1,911	4,821	8,494	**15225.37**	**86,708**
ALT B	4,721	3,161	52	**7,934**	1,733	4,528	7,811	**14071.85**	**43,274**
ALT D	4,681	2,553	34	**7,269**	3,735	8,907	14,308	**26949.91**	**26,412**
ALT E	3,385	2,456	34	**5,875**	1,922	5,297	9,177	**16396.14**	**23,422**
ALT I-1	4,736	3,132	52	**7,921**	4,395	9,590	14,979	**28964.19**	**25,712**
ALT I-2	3,930	2,760	40	**6,730**	2,433	5,377	9,940	**17750.47**	**81,371**
ALT I-3	3,300	2,519	34	**5,853**	1,957	4,930	8,896	**15782.06**	**78,421**
Average	3,734	2,706	40	6,480	2,584	6,207	10,515	19,306.00	52,189

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2.0 LAND USE—AFFECTED ENVIRONMENT

2.1 Description of Resource

Land use is a reflection of the evolution of social frameworks and of human activities in response to the natural attributes of the land. The Rio Grande has been a thread of life for centuries past and the focus of the most intensive development in New Mexico. As a source of water, fertile land, and diverse habitat, the river and its tributaries have sustained a long and diverse history of human uses. Human-modified land use categories include residential, commercial, industrial, transportation, communications and utilities, agricultural, institutional, and recreational. Management plans and zoning subdivision regulations determine the type and extent of land use allowable in specific areas and are intended to promote the use of land for the benefit of the public health, welfare, and safety.

The attributes of land use addressed in this section include land status (or categorization of land by ownership), general land use patterns and activities, land use and land management plans and zoning (where applicable), and special-use or specially protected areas.

2.2 Area of Potential Effect

Several areas of potential impact relative to human and social uses along the Rio Grande are being considered. The primary area of impact covers the floodplain of the Upper Rio Grande and the Rio Chama. Flooding directly affects existing structures and the activities they support, from residential to access. It can displace or alter existing uses either temporarily or permanently. Flooding can also incur significant costs due to disrupted enterprise and reconstruction (see Section 3.0). The area of maximum flood impact is being calculated based on a range of alternatives for this Environmental Impact Statement (EIS). This report characterizes land within 5 kilometers of the river centerline as the area of potential effect.

An area of potential effect for agricultural lands within the Upper Rio Grande Basin covers both the floodplain and land that irrigated by the surface waters of the Upper Rio Grande and its tributaries. The official irrigation districts primarily serve these areas, although they also include some land that is dry cropped and irrigated through ground water sources.

A larger affected region, defined as the Project Area, includes the entire Upper Rio Grande Basin and watershed. This region encompasses portions of several jurisdictional and planning entities. These include counties, regional water planning units, regional councils of government, and municipal bodies (such as the cities of Albuquerque and El Paso. A county and regional scale is used to evaluate social and economic impacts.

2.3 Existing Conditions

2.3.1 Land Status and Management

The Upper Rio Grande Basin encompasses over 36 million acres of land. The majority falls within the state of New Mexico (83 percent), with 13 percent in Colorado and 4 percent in Texas. Ownership of these lands is a mixture of federal, state, tribal, and private. About 8 percent of the basin is within an area of 5 km on either side of the main river channel (totaling almost 3 million acres). Almost half the surface in this buffer area is privately owned, about one-third is federally owned, and tribes hold about one-tenth as sovereign lands. Only about 4 percent of the land in the buffer area is state-owned. **Table N-2.1** summarizes the ownership of land within the 5-km buffer by reach. The upper reaches that encompass the more mountainous watersheds of the river comprise a higher proportion of federal land (at least half the land within the 5-km buffer in Reaches 1, 2, 3, 6, 7, 9, 14, and 15). The majority of the land in Reaches 8, 10, and 11 are tribal.

Table N-2.1 Land Ownership Within 5-km Buffer by Reach

Reach	Federal	Tribal	Private	State	State Park	Total Acres
1	72.7%	0.0%	19.6%	7.7%	0.0%	58,893
2	58.4%	0.0%	38.1%	3.6%	0.0%	284,564
3	52.9%	5.8%	31.7%	9.6%	0.0%	270,976
4	34.8%	19.3%	44.9%	1.0%	0.0%	38,664
5	0.0%	48.7%	51.3%	0.0%	0.0%	76,472
6	58.6%	4.7%	34.3%	2.4%	0.0%	179,061
7	54.9%	3.4%	39.5%	2.1%	0.0%	105,231
8	8.9%	72.7%	15.9%	2.4%	0.0%	52,847
9	61.4%	32.4%	5.6%	0.7%	0.0%	97,109
10	7.9%	81.8%	10.3%	0.0%	0.0%	117,624
11	5.7%	91.4%	2.7%	0.2%	0.0%	37,060
12	0.3%	21.6%	75.2%	2.9%	0.0%	133,422
13	4.5%	11.7%	83.8%	0.0%	0.0%	161,073
14	50.6%	0.0%	46.4%	3.0%	0.0%	439,926
15	65.5%	0.0%	27.5%	7.0%	0.0%	102,247
16	24.2%	0.0%	67.8%	7.9%	0.1%	526,864
17	0.0%	0.0%	99.7%	0.0%	0.3%	175,792
	1,029,007	320,014	1,392,478	115,461	865	2,857,825
Total %	36%	11%	49%	4%	<1%	100%

Source: BLM 2004; FWS and BLM 1993

Federal land is primarily managed by the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) under the authority of existing laws. The basin encompasses several national forests and BLM administrative districts (listed by reach in **Table N-2.2**). Both agencies manage public land primarily for multiple uses according to directions set in Resource Management Plans. Forestry, grazing, and recreation are predominant activities on USFS land, and grazing, mineral development, and recreation are predominant uses on BLM lands. There are also specific uses and sites on federal lands (e.g., quarries, communication towers), improvements used by permitees (e.g., water pipelines and stock tanks), and developed sites, such as campgrounds and research and monitoring site facilities. Some areas are designated or delineated for special management actions or protection, such as wilderness areas and wild and scenic river corridors.

The state of New Mexico also owns and manages land for purposes similar to those of federal land. The State also manages several sites for specific uses, including state parks, wildlife areas, and monuments. Those within the buffer zone are listed in **Table N-2.2**. Most state lands are held in trust to benefit public schools and other public institutions from the revenues they generate (in taxes, royalties, permit fees).

The majority of the reaches within the 5-km river corridor are comprised of more than one county (**Table N-2.3**). Counties may exert control over use of privately held lands, although few counties have land use-based controls in effect (such as zoning ordinances). Most counties limit development within Federal Emergency Management Agency (FEMA) floodplains by not issuing building permits for structures within designated floodplains. However, past and ongoing development, although not widespread, occurs in floodplains in some areas and is at risk from water operations, particularly during wet seasons. This issue was identified during scoping for areas along the river between the dam at Abiquiu and the confluence of the Rio Chama and Rio Grande near Española where homes have been built within the flowage easement boundaries and floodplain. Flowage easement lands are private lands that the U.S. Army Corps of Engineers (COE) has the right to flood when the need exists for the purpose of flood management. In addition, around Abiquiu Lake itself, most of the shoreline is privately owned, and owners have built private boat docks and ramps. As the lake has no authorized shoreline management plan, the construction of private docks is not permitted (Corps 2002).

Two major urban areas, the cities of Albuquerque and El Paso, also straddle the river. Use and development of lands within each city is guided by comprehensive plans and controlled through zoning ordinances.

2.3.2 Existing Land Use

Table N-2.4 summarizes the amount of undeveloped and developed land (both for agricultural and urbanized uses) for both the basin as a whole and for the 5-km buffer. Within the entire 36 million-acre basin, 9 percent of the land area is categorized as developed for urban purposes, about 2 percent is developed for agriculture, and about 89 percent is undeveloped. Overall, the vast majority of the land in the Project Area is undeveloped. From these data, it would appear that water operations would have only minimal impact on land use along the Rio Grande (e.g., from potential inundation).

Within the 5-km buffer area, a higher percentage of land has been developed for agriculture (7 percent), about 5 percent is urbanized, and 88 percent is undeveloped and natural. This illustrates the influence of the river in the process of land transformation into agricultural functions that support and sustain human activities and presence.

Table N-2.5 breaks down this same information for each reach within the 5-km buffer. Of note is the relatively high percentage of agricultural land in the Costilla Valley (Reach 2) where the Closed Basin Project provides water for agriculture. Agriculture is also more prominent south of Albuquerque in Reaches 13, 16, and 17. Urbanization is more prominent (comprising about one-fifth to one-quarter of the land area) for Reaches 9, 10, and 12. Development in Reaches 9 and 10 reflects the presence of the railway corridor; Reach 12 encompasses the Albuquerque metropolitan area.

Table N-2.2 Designated Areas and Jurisdictional by Reach (Within the 5-km Buffer)

Reach	Federal	Tribal Lands	State	County
1	• Alamosa NWR (USFWS) • San Luis Hills WSA • La Jara FO (BLM)		• Colorado state lands	• Alamosa, Costilla, Conejos
2	• Rio Grande NF (USFS) • South San Juan Wilderness (Rio Grande NF) • San Luis Hills WSA • La Jara FO (BLM)		• Conejos River SWA • Sego Springs SWA	• Conejos, Rio Grande
3	• Taos FO (BLM) • Rio Grande Wild and Scenic River • Wild Rivers (BLM) • Orilla Verde Recreation Area (BLM) • Carson NF (USFS)	• Taos • Picuris	• Red River Hatchery (NMDGF) • Rio Grande Gorge SP	• Taos, Rio Arriba

Reach	Federal	Tribal Lands	State	County
4	• Taos FO (BLM) • BLM public lands	• San Juan	• New Mexico state lands	• Rio Arriba
5	• Taos FO (BLM) • Albuquerque FO (BLM)	• Jicarilla Apache	• Rio Chama State Recreation Area • Rio Chama SWA • Heron Lake SP • El Vado Lake SP	• Rio Arriba
6	• Santa Fe NF (USFS) • Chama River Canyon Wilderness (Santa Fe NF) • Chama River Wild and Scenic River • Carson NF (USFS) • Taos FO (BLM)	• Jicarilla Apache	• El Vado Lake SP • Heron Lake SP	• Rio Arriba
7	• Carson NF (USFS) • Santa Fe NF (USFS) • Taos FO (BLM)	• San Juan	• New Mexico state lands	• Rio Arriba
8	• Taos FO (BLM) • Santa Fe NF (USFS)	• San Juan • Santa Clara • Pojoaque • San Ildefonso	• New Mexico state lands	• Rio Arriba, Santa Fe, Los Alamos
9	• Santa Fe NF (USFS) • Dome Wilderness (SFNF) • Bandelier NM (NPS) • Bandelier Wilderness • Taos FO (BLM) • Albuquerque FO (BLM)	• Cochiti • San Ildefonso	• New Mexico state lands	• Santa Fe, Sandoval
10	• Santa Fe NF (USFS) • Taos FO (BLM) • Albuquerque FO (BLM)	• Cochiti • San Felipe • Santa Ana • Santa Domingo		• Santa Fe, Sandoval
11	• Albuquerque FO (BLM)	• San Felipe • Santa Ana • Zia	• New Mexico state lands	• Sandoval
12	• Cibola NF • Sandia Military Reservation • Albuquerque FO (BLM)	• Sandia • Isleta	• Coronado SP • Coronado SM • Rio Grande Nature Center SP • Indian Petroglyph SP	• Santa Fe, Sandoval, Bernalillo
13	• Sevilleta NWR • Albuquerque FO (BLM) • Socorro FO (BLM)	• Isleta	• Senator Willie M. Chavez SP • La Joya Waterfowl Area • Belen Waterfowl Area • Bernardo SWA (NMDGF)	• Bernalillo, Valencia

Reach	Federal	Tribal Lands	State	County
14	• Sevilleta NWR • Bosque del Apache NWR • Bosque del Apache Wilderness • San Lorenzo Canyon (BLM) • The Box (BLM) • Socorro FO (BLM) • Las Cruces FO (BLM)		• Elephant Butte Lake SP • Fort Craig SM	• Valencia, Socorro, Sierra
15	• BLM public lands • Las Cruces FO (BLM)		• Caballo Lake SP • Elephant Butte Lake SP	• Sierra
16	• Organ Mountains Recreation Area (BLM) • Las Cruces FO (BLM)		• Percha Dam SP • Caballo Lake SP • Leasburg Dam SP • Fort Selden SM • Franklin Mountains SP	• Sierra, Doña Ana, El Paso, Mexico
17	• Chamizal National Memorial • Fort Bliss Military Reservation • Feather Lake Wildlife Sanctuary • Fort Quitman		• Franklin Mountains SP	• El Paso, Hudspeth, Mexico

Sources: NMRHG 1992; NAUS et al. 2003; GDT and ESRI 2003; BLM 2002a,b; NMDGF 2004

BLM	Bureau of Land Management	SFNF	Santa Fe National Forest
FO	Field Office	SM	State Monument
NF	National Forest	SP	State Park
NM	National Monument	SWA	State Wildlife Area
NMDGF	New Mexico Department of Game and Fish	USFS	U.S. Forest Service
NPS	National Park Service	USFWS	U.S. Fish and Wildlife Service
NWR	National Wildlife Refuge	WSA	Wilderness Study Area

Table N-2.3 County Jurisdictions in 5-km Buffer Along Upper Rio Grande and Rio Chama

Reach	5-km Buffer Acreage	County Association
1	158,991	Alamosa, Costilla, Conejos
2	284,564	Conejos, Rio Grande
3	271,015	Taos, Rio Arriba
4	38,664	Rio Arriba
5	76,914	Rio Arriba
6	179,061	Rio Arriba
7	105,231	Rio Arriba
8	52,847	Rio Arriba, Santa Fe, Los Alamos
9	97,109	Santa Fe, Sandoval
10	117,624	Santa Fe, Sandoval
11	37,060	Sandoval
12	133,422	Santa Fe, Sandoval, Bernalillo
13	161,073	Bernalillo, Valencia
14	439,926	Valencia, Socorro, Sierra
15	102,247	Sierra
16	404,981	Sierra, Doña Ana, El Paso
17	175,792	El Paso, Hudspeth, Mexico
	2,857,825	

Source: BLM 2004; FWS and BLM 1993

Table N-2.4 General Land Characteristics in Project Area and 5-km Buffer

Type of Land	Project Area		5-km Buffer	
	Acres	%	Acres	%
Undeveloped/natural	32,305,802	89%	2,474,656	88%
Developed/agriculture	795,610	2%	184,530	7%
Developed/urbanized	3,272,711	9%	152,184	5%
Total	**36,374,123**	**100%**	**2,811,370**	**100%**

Source: Derived from USGS and EPA 2000.

Table N-2.6 provides a more detailed accounting of land use and land cover for the entire project area. The table shows that most of the area is herbaceous grassland, shrubland, and evergreen forest. Using the same classifications, **Table N-2.7** indicates that only 10 percent of the land within the 5-km buffer of Reach 12 (the Albuquerque area) is herbaceous grassland. A larger portion of undeveloped land is shrubland and bare rock or sand and clay. About 16 percent of land is developed in low-intensity residential development and about 5 percent and is used to grow pasture crops. The variance in these data to those in **Table N-2.5** is due partially to differences in classification categories, but also time and methodology.

2.3.3 Future Land Use and Trends

Several planning initiatives are underway for different parts of the Project Area, both at the regional and local scale. Many of these are focusing on issues related to future growth and development, including land use, transportation, and water resources planning. Most of these efforts are built around future population projections, with likely scenarios both in terms of numbers of people and distribution. For the purpose of this study, development in the Project Area contributes to runoff that reenters the river system. The Upper Rio Grande Water Operations Model (URGWOM) accounts for storm water and treated wastewater inputs at certain locations along the existing channel. As land changes from essentially undeveloped or pervious land into urbanized areas with varying degrees of permeability, this results in changes to these inputs. Both the U.S. Geological Survey (USGS) and the Mid-Region Council of Governments (MRCOG) have been studying change in land use and developing future land use framework based on trends and certain assumptions for projected growth. Some statistics highlighting the degree of change over time in the Middle Rio Grande Basin study by USGS (USGS 2000) are as follows:

- In the Albuquerque area, irrigated land declined from 14,000 acres in 1975 to 9,600 acres in 1992;
- The Albuquerque area accounts for 90 percent of the residents in the MRGB;
- The metropolitan area grew 70 percent (by 35,000 acres) between 1973 and 1991, and grew from 2,000 acres in 1891 to 103,000 acres in 1995;
- The MRGB population is estimated to increase from approximately 700,000 persons today to about 1.55 million by 2050.

The USGS and MRCOG have developed multiple scenarios of future development for the Middle Rio Grande Basin, based on differing assumptions about growth, trends, and land use patterns. **Table N-2-8** summarizes the existing land use inventory compiled of both current and projected future land use for the MRGB, based on a reasonable estimation for future development. The table indicates a reduction in agricultural land (both irrigated and dry) and vacant (undeveloped land). By 2025, the percentage of residential land, and to a lesser degree, commercial and industrial land, is projected to increase along the river. With this trend will come additional pavement, increasing the volume of storm water runoff. This may contribute to local inflows to the river.

Table N-2.5 General Land Characteristics by Reach Within the 5-km Buffer of the Upper Rio Grande and Rio Chama

5-km buffer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
Undeveloped/ natural	150,262	243,583	269,835	36,579	74,046	178,643	96,956	45,246	76,612	83,791	37,030	92,885	126,325	426,899	99,665	339,853	96,446	2,474,656
Developed/ agriculture	7,111	39,718	833	1,657	2,815	82	2,158	2,716	26	4,344	0	7,436	22,666	10,441	665	46,665	35,196	184,530
Developed/ urbanized	1,617	1,262	348	427	53	336	6,116	4,885	20,471	29,488	30	33,103	12,081	2,586	1,917	13,292	24,172	152,184
Total	**158,990**	**284,563**	**271,016**	**38,664**	**76,914**	**179,061**	**105,231**	**52,847**	**97,109**	**117,623**	**37,060**	**133,423**	**161,072**	**439,926**	**102,247**	**399,810**	**155,814**	**2,811,370**
% by Reach																		
Undeveloped/ natural	95%	86%	100%	95%	96%	100%	92%	86%	79%	71%	100%	70%	78%	97%	97%	85%	62%	88%
Developed/ agriculture	4%	14%	0%	4%	4%	0%	2%	5%	0%	4%	0%	6%	14%	2%	1%	12%	23%	7%
Developed/ urbanized	1%	0%	0%	1%	0%	0%	6%	9%	21%	25%	0%	25%	8%	1%	2%	3%	16%	5%

Source: Derived from USGS and EPA 2000.

Table N-2.6 Generalized Land Use/Land Cover Characteristics for the Project Area

Land Cover	Acres				% of Project Area
	Texas	New Mexico	Colorado	Total	
No Data	—	399,720	—	399,720	1.1%
Open Water	1,100	96,537	21,009	118,647	0.3%
Perennial Ice/Snow	—	1	1,288	1,289	0.0%
Low-Intensity Residential	30,254	76,258	4,894	111,406	0.3%
High-Intensity Residential	—	1,284	863	2,147	0.0%
Commercial/Industrial/Transportation	28,006	3,088,064	3,186	3,119,256	8.6%
Bare Rock/Sand/Clay	95,492	1,054,263	101,087	1,250,842	3.4%
Quarries/Strip Mines/Gravel Pits	2,700	26,102	—	28,801	0.1%
Transitional	—	1,879	1,253	3,132	0.0%
Deciduous Forest	127	94,030	199,162	293,319	0.8%
Evergreen Forest	188	5,755,357	1,262,865	7,018,410	19.3%
Mixed Forest	—	41,480	40,213	81,693	0.2%
Shrubland	646,076	6,431,474	1,161,941	8,239,491	22.7%
Orchards/Vineyards/Other	1,100	6,720	—	7,820	0.0%
Grasslands/Herbaceous	442,773	12,913,269	1,511,258	14,867,300	40.9%
Pasture/Hay	7,005	89,500	283,868	380,373	1.0%
Row Crops	40,021	123,813	220,203	384,038	1.1%
Small Grains	—	20,066	—	20,066	0.1%
Fallow	—	3,313	1	3,314	0.0%
Urban/Recreational Grasses	715	7,228	26	7,969	0.0%
Woody Wetlands	—	4,746	458	5,204	0.0%
Emergent Herbaceous Wetlands	99	3,908	25,881	29,887	0.1%
Total Acres	**1,295,655**	**30,239,012**	**4,839,456**	**36,374,123**	**100.0%**
Percent of Project Area Within State	4%	83%	13%	100%	

Source: USGS and EPA 2000

Table N-2.7 General Land Use/Land Cover in Reach 12

Land Use	Acres	Percent
No Data	1,646	1%
Open Water	125	0%
Perennial Ice/Snow	0	0%
Low-Intensity Residential	20,959	16%
High-Intensity Residential	201	0%
Commercial/Industrial/Transportation	9,444	7%
Bare Rock/Sand/Clay	28,430	21%
Quarries/Strip Mines/Gravel Pits	721	1%
Transitional	0	0%
Deciduous Forest	38	0%
Evergreen Forest	751	1%
Mixed Forest	38	0%
Shrubland	46,586	35%
Orchards/Vineyards/Other	440	0%
Grasslands/Herbaceous	13,245	10%
Pasture/Hay	6,800	5%
Row Crops	163	0%
Small Grains	33	0%
Fallow	0	0%
Urban/Recreational Grasses	1,778	1%
Woody Wetlands	1,827	1%
Emergent Herbaceous Wetlands	198	0%
Totals	**133,423**	**100%**

Source: USGS and EPA 2000

Table N-2.8 General Land Use/Land Cover in Reach 12

Land Use	Current		2025	
	Acres	Percent	Acres	Percent
Residential—Single Family	32,406	25	44,208	35
Residential—Multi-Family	1,324	1	2,154	2
Commercial—Major	456	<1	781	1
Commercial—Minor	3,342	3	5,332	4
Office	475	<1	757	1
Industrial	5,305	4	6,326	5
Institutional	180	<1	537	<1
Schools/Universities	1,950	2	2,183	2
Airport	1,755	1	1,629	1
Transportation/Utility	173	<1	158	<1
Urban—Vacant	17,388	14	5,997	5
Landfill/Sewage	269	<1	257	0
Urban—Non-Residential	902	1	1,254	1

Land Use	Current		2025	
	Acres	Percent	Acres	Percent
Agriculture—Irrigated	7,564	6	5,723	4
Range—Dry Agriculture	35,220	28	31,160	24
Open—Parks	9,439	7	9,756	8
Riparian	9,439	7	9,375	7
Kirtland Air Force Base	150	<1	148	<1
Total	**127,726**	**100**	**127,726**	**100**

Source: MRCOG 2002

2.3.4 Specially Managed Areas

There are federal- and state-run lands in each of the reaches within the 5-km buffer of the Rio Grande corridor. **Table N-2.2** provides a list of these entities and special areas that they manage, for example, parks, wildlife refuges, and recreation areas. These areas can be directly affected by water operations (such as inundation). Areas that have a recreation emphasis are described in more detail in the Recreation section. As described above, federal lands are mostly managed according to goals and objectives described in land and resource management plans. Of particular interest are several wildlife refuges that have specific purposes for protecting wildlife and whose functioning is interdependent on the riparian environment and water deliveries from the river.

Most prominent among the wildlife areas in the basin is the Bosque del Apache National Wildlife Refuge (NWR) established in 1939 and located in Reach 14. Its main purpose is to serve as a refuge and breeding grounds for migratory birds. These include aquatic birds such as the sandhill crane (whose population has increased from 14 individuals to 20,000 individuals since 1939), the whooping crane, and lesser snow geese, as well as Neotropical songbirds such as the yellow-billed cuckoo and southwestern flycatcher. The Bosque del Apache NWR is also a designated critical habitat for the Rio Grande silvery minnow. Refuge management habitat programs focus on managing wetlands and providing essential winter food resources, such as agriculturally grown and maintained grains in the “managed” part of the refuge. The areas located on the west side of the levees use both surface and groundwater sources. The refuge has access to five points of surface diversion and 16 wells. The interaction of water sources with the LFCC is complex, but so long as the LFCC is in place, whether serving as a canal with diverted water, or as a drain (without diverted water), it provides a dependable source of surface water for the refuge. Ground water from the wells can supplement surface water diversions. When the LFCC is empty (or not being used for diversion), is acts as a drain, leaving the river less wet. This can affect habitat on the east side of the levees. These areas are not actively managed by the refuge (Dello Russo 2004).

The Sevilleta NWR, established in 1973, is also located in Reach 14. Management programs have focused on returning the area to the natural conditions. A wide range of native mammals (elk, deer, coyotes, mountain lions), birds (bald eagles, peregrine falcons, great blue herons, sandhill cranes, burrowing owls), and reptiles (the endangered horned lizard) has become more abundant since the establishment of the refuge. In addition, there are special endangered species release programs devoted to acclimating the Mexican wolf and the desert bighorn sheep. All of these programs use water from the Rio Grande as part of the growth of breeding habitat and essential food resources.

2.3.5 Wilderness and Wild and Scenic Rivers

The Wild and Scenic River (W&SR) designation applies to 64 miles of the Rio Grande in the Project Area in northern New Mexico (Reach 3). The Rio Grande W&SR is jointly managed by BLM and the

Carson National Forest. Of this, 48 miles in the Upper Gorge is managed for both wild and scenic values, and 12 miles in the Lower Gorge (south of Taos Junction Bridge) is designated as scenic. Maintaining the visual qualities of these areas is a high priority. They also offer exceptional recreational opportunities for rafting and kayaking and limited camping along the river (see Recreation) (BLM 2000). In Colorado, 41 miles are under interim protection pending W&SR designation (Reach 1).

The Rio Chama Canyon Wilderness straddles the Rio Chama River below El Vado Lake (Reach 6). The Wilderness lies in Santa Fe National Forest, with a portion in Carson National Forest. A 6-mile stretch of the Rio Chama has the W&SR designation. It is also very popular for both personal and outfitter rafting and kayaking use. Trail access is poor above the sandstone bluffs. A few put-ins provide access for rafts, kayaks and canoes, which are the primary means of enjoying this area.

2.3.6 Tribal and Pueblo Lands

The Upper Rio Grande Basin includes almost 2.6 million acres of sovereign lands. The 5-km buffer includes about 320,000 acres and 16 discrete pueblo and tribal entities, and accounts for most of the land immediately adjacent to the river in Reaches 8, 10, and 11. Deliveries of surface water are made to tribes and pueblos for "municipal and industrial" use, agriculture, and other customary uses. Tribes and pueblos manage their lands according to their own policies and purposes. As part of interagency and intergovernmental coordination for this project, tribal and pueblo governments have been contacted.

2.4 Land Use—Impact Analysis

2.4.1 Issues and Concerns

Primary concerns that could affect land use include:

- Maintaining reliable water delivery for agricultural and municipal and industrial purposes;
- Public safety and flood control;
- Damage to property and productive uses from inundation;
- Land conversion from agriculture to developed use; and
- Impacts of flooding on specially managed areas and recreational opportunities.

2.4.2 Limitations and Assumptions

- The analysis is limited to reaches 6, 7, 8, 9, 10, 12, 13, and 14. Other reaches are not influenced by operations under the authority or review of this effort. Operations for flood control (below Elephant Butte reservoir) would not vary between alternatives.
- Operations will not cause changes in overall land status and ownership.
- All levees function adequately and areas protected by levees will not be inundated.

2.4.3 Evaluation Criteria

Three overall criteria were assessed for desirable land uses:

- Degree to which an alternative promotes recreational use;
- Degree to which an alternative preserves suitable conditions for agriculture;

- The degree to which damage to property or loss of productive uses is minimized.

2.4.4 Impact Analysis

Table N-2.9 summarizes overall performance on the three evaluation criteria above. These reflect a roll-up of performance on the indicator measures in report N-1 (Agriculture), report N-5 (Recreation), and report N-3 (Flood Control). The values are "weighted", according to the **Table N-2.10** provides the values used to generate the relative value of damages for each alternative.

Table N-2.9 Desirable Land Use Performance

Criteria	No Action	Alt B-3	Alt D-3	Alt E-3	Alt I-1	Alt I-2	Alt I-3
Minimizes damages	6.6	9.0	9.8	8.6	7.4	8.8	9.8
Promotes Recreation	5.3	5.6	5.9	6.0	5.0	5.5	6.0
Promotes agriculture	7.7	8.3	6.6	7.9	7.6	7.7	7.9
Total score	19.6	22.9	22.3	22.5	19.6	22.0	23.7
Ranking	7	2	4	3	6	5	1

Table N-2.10 Evaluation of Flood Damage

Summary of desirable uses - derived from start of damages values

	Reach 7	Reach 9	Reach 12	Reach 13	Reach 14	Total
No Action	4,970.60	202,656.50	3,111.40	0.00	4,269,805.00	4,480,543.50
ALT B	1,280.40	151,776.50	51,414.30	35,980.00	1,054,421.00	1,294,872.20
ALT D	4,091.00	175,294.00	690.20	0.00	53,729.00	233,804.20
ALT E	2,810.10	162,659.60	84,657.40	53,111.70	1,462,439.00	1,765,677.80
ALT I-1	4,775.10	200,740.40	784.90	0.00	3,228,308.00	3,434,608.40
ALT I-2	3,560.30	183,190.40	696.40	0.00	1,431,151.00	1,618,598.10
ALT I-3	2,835.60	166,405.30	653.60	0.00	52,708.00	222,602.50
	24,323.10	1,242,722.70	142,008.20	89,091.70	11,552,561.00	13,050,706.70
	Reach 7	**Reach 9**	**Reach 12**	**Reach 13**	**Reach 14**	**Total**
No Action	20%	16%	2%	0%	37%	34%
ALT B	5%	12%	36%	40%	9%	10%
ALT D	17%	14%	0%	0%	0%	2%
ALT E	12%	13%	60%	60%	13%	14%
ALT I-1	20%	16%	1%	0%	28%	26%
ALT I-2	15%	15%	0%	0%	12%	12%
ALT I-3	12%	13%	0%	0%	0%	2%

Score for damages (high score is lower damage values)

	Reach 7	Reach 9	Reach 12	Reach 13	Reach 14	Total
No Action	80%	84%	98%	100%	63%	66%
ALT B	95%	88%	64%	60%	91%	90%
ALT D	83%	86%	100%	100%	100%	98%
ALT E	88%	87%	40%	40%	87%	86%
ALT I-1	80%	84%	99%	100%	72%	74%
ALT I-2	85%	85%	100%	100%	88%	88%
ALT I-3	88%	87%	100%	100%	100%	98%

2.4.5 No Action

Under the No Action, land use would continue to evolve along the river in response partially to climatic events, but more in response to jurisdictional and management controls, and to some degree market-driven forces and population growth.

Delivery of water for municipal and industrial purposes is a priority. The recently approved State Water Plan provides the framework and vision for equitable and wise use of water into the future. Delivery of water for agriculture is addressed above under agriculture. The Isleta diversion in the Central section will continue to experience significant shortfalls from the amount of water requested under the No Action.

Appendix N3 reports the projected value of damages resulting over the project life for each alternative. The No Action recorded the highest potential losses, mostly in the San Acacia section (**Table N-2.10**). Section 4.2.7 provides an evaluation of economic impacts of damages from flooding on structures and land use. FLO2 D model outputs of the spatial extent and duration of inundation over the 40-year project period show localized areas of inundation, mostly within the historic floodplain. When viewed in combination with aerial photography, none of the inundated land south of Bernalillo appears to have the characteristics of agricultural land. These areas are either natural and undeveloped, or used for grazing and dispersed recreation. A few structures south of Bernardo may be at risk of flooding.

Overall, periodic inundation immediately along the river would not alter land use patterns that have evolved in response to periodic flood events and controls on development in floodplains. These issues may continue to be a local problem, for example, in floodplain lands near the confluence. Coordination between county planning and permitting officers and the water operators should continue. This effort should emphasize the need to control encroachment in order to protect public safety and preserve flexibility for water operators. Similarly, management and control of private development in public flood easements, particularly around Abiquiu Lake, would provide flexibility for operators to meet multiple objectives and prevent incompatible encroachment in the future. Establishing approved management plans for use of lands in flood easements around reservoirs is recommended.

Water operations under the No Action would not cause change in the distribution of private versus publicly held or sovereign land. Stream flows and inundation would continue to be a variable for managers of public land along the river, particularly in relation to habitat management, recreation and grazing activities. However, continuation of current water operations is not expected to exert pressures that would change the use of these areas. Special consideration of agricultural and recreational uses along the river is addressed in more detail in Appendix N1 and N5, respectively.

2.4.6 Alternative B-3

This alternative provides relatively good performance for all criteria, and is preferable for agriculture (**Table N-2.9**).

2.4.7 Alternative D-3

This alternative performs well on limiting damage to property and uses, but is least beneficial overall for agriculture.

2.4.8 Alternative E-3

This alternative is balanced in terms of providing satisfactory conditions for developed uses along the river.

2.4.9 Alternative I-1

Alternative I-1 is least beneficial for recreation, and average for agriculture and impact of flood damage.

2.4.10 Alterative I-2

Alternative I-2 is balanced but not preferred in terms of promoting desirable land use conditions.

2.4.11 Alternative I-3

Overall, this alternative provides the most favorable conditions for human activity along the river.

3.0 FLOOD CONTROL

3.1 Introduction

There are many flood control structures along the Rio Grande and its tributaries, from dams to levees. There have been no property damages sustained nor anticipated from direct releases by the flood control facilities under consideration by this EIS. However, residual flood damages from unregulated drainages could occur depending on flows. Evaluation of alternatives, therefore, focuses on changes in residual flood damages associated with the proposed operation changes. The affected environment includes the current flood control structures and benefits, as well as the areas that remain threatened by floods.

3.2 Relevant Affected Geographic Area and Historical Flooding

Total flood control benefits from Corps projects along the Rio Grande and its tributaries since their inception through 2002 have totaled over $1 billion (Corps 2003). In addition, there are significant damages prevented in terms of river sedimentation. There are many other projects along the Rio Grande that have prevented significant flood damages as well. These include Elephant Butte/Caballo, El Vado, the International Water Boundary Commission levees on the Rio Grande, and numerous dams constructed by the Natural Resources Conservation Service. The benefits computed for Corps projects are as follows:

Table N-3.1 Cumulative Flood Control Benefits in the Rio Grande Basin for U.S. Army Corps of Engineers Projects

($000)	
Project	**Flood Control Benefits**
Abiquiu	386,499
Cochit	431,787
Jemez Canyon	23,227
Platoro	6,049
Socorro	580
Rio Grande Floodway	48,759
Albuquerque Diversions	
North	171,281
South	6,491
El Paso	12,023
Willow Creek	331

*Note that estimates for these benefits are conservative. Past years have not been adjusted to current dollars. Total through fiscal year 2003.

There are seven primary areas that have received damages as a result of flooding from the Rio Grande since 1979.

- First, some agricultural damages and some minor damages to structures have been sustained in areas of Colorado (Del Norte, Monte Vista, and Alamosa). There were no Corps flood control projects in these areas at the time of the damage, although a levee system for Alamosa was completed in 1999.

- Second, damages have occurred along the Rio Grande from Pilar, New Mexico, to the confluence of the Rio Chama during several high runoff years since 1979. Losses have occurred primarily to bridges, diversion structures, pastures, orchards, and low lying agricultural areas.
- Third, minor bank erosion damages have been periodically sustained between Abiquiu Dam and Cochiti Lake along the Rio Chama and the Rio Grande.
- Fourth, major damages have been sustained in Mexico in 1986 and 1987 as a result of 14 levee breaks resulting from high flows on the Rio Grande. Both structures and a significant amount of agricultural land were destroyed and/or damaged.
- Fifth, high flows in the Rio Grande in El Paso County, Texas, in 1986 caused damage to pecan orchards and to the diversion structure of an irrigation district. Pecan orchards were primarily damaged from the high groundwater table resulting from the Rio Grande flows. The Riverside Diversion was permanently damaged from high river flows.
- Sixth, damages occurred in Hudspeth County, Texas, where high releases from Elephant Butte in 1986 and 1987 caused damage primarily to agricultural lands. The total damage estimated from the 1986 Elephant Butte Reservoir releases includes over $1,000,000 to clean up sediment; over $200,000 in pump purchases and operation to prevent the Hudspeth County. Irrigation drainage ditches from overflowing; $220,000 in lost yields and production (compensable by the Agricultural Stabilization and Conservation Services); and an immeasurable impact on future yields due to increased salinity.
- Seventh, high reservoir levels at Elephant Butte increased the amount of sedimentation at the head of the reservoir, thus creating a risk of river flows overtopping the levee and flooding the low flow conveyance channel.
- Lastly, damages have occurred on many of the tributaries to the Rio Grande (e.g. Hatch, NM and parts of Socorro County), however these are not included in this analysis since operating plans cannot impact these areas.

3.3 Potential Effects (Properties Impacted/ Average Annual Damages)

Potential flood effects occur at all the locations listed above. In addition, there are several areas along the Rio Grande that have not experienced flooding recently, but as a result of the deterioration of a non-engineered levee or other facilities, are prone to flooding at certain flows. These areas include Española, from Bernalillo to Belen, and from San Acacia to Elephant Butte. All of these areas are currently being analyzed in studies by the Corps of Engineers.

For purposes of currently available flood control analysis the Rio Grande and Tributary floodplains are broken down into several reaches.

- The upper reach is comprised of the Rio Grande as it flows through Colorado, primarily centered upon Del Norte, Monte Vista, and Alamosa.
- The next reach is comprised the area from Pilar, New Mexico through Española.
- The third reach is the Chama Valley from Abiquiu to the Rio Grande.
- The fourth reach is from Bernalillo to Belen.
- The fifth reach is from San Acacia to Elephant Butte.

- The sixth reach is in Hudspeth County to the east of El Paso. There are other areas that do not currently have flood control analysis, but there are potential damages. These include the area from Elephant Butte through El Paso, several points on the river north of Bernalillo, Mexico, and the area east of Fort Quitman.

Information regarding damages to Mexico is currently not available. Most damages in this reach are not readily converted into a damage-flow curve, because many occur from a rise in groundwater rather than direct overflow.

The following table (**Table N-3.2**) indicates the number of properties in each of the identified damage centers by quantity that is subjected to flooding by the events indicated. During the initial studies (date presented within the table), Corps hydraulic engineers developed floodplains and event stages for specific frequency flood events, which was then inventoried by Corps economists to determine the number and value of damageable property, as well as the single occurrence damages associated with each event. Some of these studies predate new GIS-related tools so data other than the flow-damage relationship is unavailable. Note that some growth may have occurred since the initial study, and further growth is expected, such that the damages associated with specific frequency events will be higher than indicated.

Table N-3.2 Number of Properties Subject to Flooding

Area	Study date		Storm Frequency and Number of Structure					
		Event						
Del Norte	-1986	Structures						
		Event						
Monte Vista	-1987	Structures						
		Event	100 yr	500 yr				
Alamosa	-1987	Structures	1026	1657				
		Event	25 yr	50 yr	100 yr	500 yr		
Española	-1995	Structures	111	138	163	215		
San Acacia to		Event	7 yr	10 yr	50 yr	100 yr	500 yr	
Elephant Butte	-1998	Structures	0	1010	1310	1384	1430	
		Event						
Hudspeth County,	-1989	Structures						
		Event	5 yr	25 yr	50 yr	100 yr	500 yr	
Velarde	-1991	Structures	0	18	24	34	55	
		Event	5 yr	25 yr	50 yr	100 yr	500 yr	
Lyden	-1991	Structures	0	18	24	34	55	
		Event	2 yr	10 yr	25 yr	50 yr	100 yr	500 yr
Abiquiu to Española	-1996	Structures	0	16	19	19	21	
		Event	13 yr	25 yr	50 yr	100 yr		SPF(625 yr)
Corrales	-1994	Structures	0	61	72	81	1218	
		Event	100 yr	270 yr				
Albuquerque	-1977	Structures	0	35564				
		Event	7 yr	10 yr	25 yr	100 yr	500 yr	
Belen	-1997	Structures	0	171.1778	12418.7	12452.72	12452.57	

Note: In some cases, historical data omits number of structures though includes damage computations.

The following tables indicate the degree to which damages may be expected for given flows in the river, and represent the flow-damage relationship the Corps develops to compute the significance of a flood risk when considering flood control measures. Each flow is associated with a respective frequency, which is also indicated on the table. While this table is important in that it shows total damages (shown here in thousands of dollars) that can be expected for an event, it does not indicate at what point damages will start which is particularly important for this EIS to ensure that no alternative increases flood damages. Additionally, the table indicates the environment at the point in time the study was completed. There are expected levee projects by the U.S. Army Corps of Engineers that will impact the expected damages from San Acacia–Bosque del Apache, Bernalillo to Belen and Española Valley.

Table N-3.3 Degree to Which Damage May be Expected

Del Norte		CFS	**7,500**	**9,800**	**11,000**	**12,000**	**18,000**				
	-1986	Damages	$0	$709	$863	$989	$2,775				
		Event									
		# Structures									
Monte Vista		CFS	**7,000**	**9,900**	**13,000**	**16,800**					
	-1987	Damages	$0	$1,949	$12,292	$43,703					
		Event		10 yr	100 yr	500 yr					
		# Structures									
Alamosa		CFS	**4,800**	**6,300**	**7,100**	**9,000**	**10,000**	**10,900**	**N/A**	**N/A**	**18,000**
	-1987	Damages	$2,175	$6,359	$7,824	$11,299	$27,370	$34,233	$42,942	$57,721	$63,918
		Event	10 yr	20 yr	25 yr	50 yr	75 yr	100 yr	150 yr	300 yr	500 yr
		# Structures				371		1026			1657
Española		CFS	**5,100**	**11,000**	**14,500**	**17,000**	**20,000**	**27,000**			
	-1995	Damages	$0	N/A	$3,234	$4,710	$6,773	$11,124			
		Event	2 yr	10 yr	20 yr	50 yr	100 yr	500 yr			
		# Structures			111 (25 yr event)	138	163	215			
San Acacia to Elephant Butte		CFS	**5,000**	**8,000**	**19,000**	**28,000**	**72,000**				
		Damages	$0	$79,300	$131,089	$136,716	$153,618				
	-1998	Event	7 yr	10 yr	50 yr	100 yr	200 yr				
		# Structures	0	1010	1310	1384	1430 (500 yr event)				
Hudspeth County, Texas (1989)		CFS	**1,500**	**2,000**	**2,500**	**3,000**	**4,000**				
		Damages	$869	$2,640	$4,352	$5,967	$7,583				
		Event									
		# Structures		(Predominantly agricultural damages)							
Velarde		CFS	**7,200**	**15,000**	**17,900**	**21,200**	**29,800**				
	-1991	Damages	$0	$997	$1,567	$1,935	$2,610				
		Event	5 yr	25 yr	50 yr	100 yr	500 yr				
		# Structures	0	18	24	34	55				
Lyden		CFS	**10,000**	**15,000**	**17,900**	**21,200**	**29,800**				
	-1991	Damages	$0	$1,225	$1,643	$2,137	$2,358				
		Event	10 yr	25 yr	50 yr	100 yr	500 yr				

		# Structures	0	45	45	45	45		
Abiquiu to Española		CFS	**4,200**	**5,600**	**7,600**	**9,900**	**12,000**	**22,000**	
	-1996	Damages	$0	$191	$277	$339	$380	$542	
		Event	2 yr	10 yr	25 yr	50 yr	100 yr	500 yr	
		# Structures	0	16	19	19	21	29	
Corrales		CFS	**7,054**	**8,700**	**14,540**	**23,270**	**42,000**	**73,900**	
	-1994	Damages	$0	$613	$1,184	$1,589	$67,714	$76,096	
		Event	13 yr	25 yr	50 yr	100 yr	270 yr	SPF(625 yr)	
		# Structures	0	61	72	81	0	1218	
Albuquerque		CFS	**41,999**	**42,000**	**42,001**	**44,000**	**50,000**	**60,000**	**72,000**
	-1977	Damages	$0	$323,061	$1,542,482	$1,588,823	$1,681,504	$1,840,386	$2,025,749
		Event	100 yr	270 yr					
		# Structures	0		35564				
Belen		CFS	**7,054**	**7,595**	**12,900**	**17,500**	**32,000**		
	-1997	Damages	$0	$677	$261,751	$284,696	$291,025		
		Event	7 yr	10 yr	50 yr	100 yr	500 yr		
		# Structures	0	171	12419 (25 yr)	12453	12453		

1

3.4 General Computational Procedures

The assumptions and procedures used to analyze and quantify the economic variables are presented in this section. The hydro-economic model used to develop expected annual damages is based on discharge-frequency, stage-frequency, and stage-damage curves used to develop a damage-discharge curve. Stage-percent damage curves express dollar damages resulting from varying depths of water based on a percentage of the value of structure and contents.

Each surveyed property was assigned to a category (*e.g.*, commercial, residential, public, outbuilding, transportation facilities, utilities, and vehicles) with as many subcategories (*e.g.*, contents) as necessary. Details of ground and first floor elevations were also noted. The depth-damage relationship for each category was expressed as a cumulative percentage of value for each foot of inundation. The depth-damage relationships were derived from historical data obtained from insurance companies, a commercial content survey, the Flood Insurance Administration, and Corps of Engineers data and experience. Note that the 2001 residential curves developed by the Institute of Water Resources (IWR) were used; thus, the residential content damages are a direct relationship to structure value.

***Value of Property*—**A survey of structures within the floodplain was conducted to evaluate the flood threat to each damage center**. Table N-3.3** indicates the date of that survey. Property categories surveyed include residential, commercial, public buildings, vehicles, transportation facilities, utilities, and outbuildings (*e.g.*, sheds and detached garages).

Depreciated, replacement residential structure values were computed using local experts such as realtors, appraisers, and builders. The properties were then compared to actual sales data in the area and field inspected for consistency and first floor elevations.

Content values were estimated from several sources. Residential content values were fixed at 50 percent of the structure value. Generally, property insurers estimate content values at greater than 55 percent of structure value. Commercial and public content values were estimated primarily from surveys of similar establishments and interviews.

Vehicle estimates were be determined using in-house data and published surveys. It is assumed that all business-related vehicles would have been evacuated from the floodplain. Therefore, the vehicles that would remain in the floodplain would be associated with residential structures and apartments. Census data or locally available information was used to determine the per capita vehicles per household. It was assumed that 1 of these vehicles was driven out of the floodplain. The remaining vehicles will be distributed among the residential structures located within the 0.2 percent chance exceedance floodplain.

3.5 Impact of Future Development

Future development would change potential damages from any flood event. While future population estimates in the planning area are important, the quantity of that development that occurs within the floodplain is the relevant aspect and is a rough estimate at best. Note that any future development that occurs should follow FEMA requirements and be elevated to the 100-year flood event.

3.6 Analysis of Alternatives

URGWOM daily stream gage flow projections were retrieved to estimate at locations near damage centers identified above for the No Action alternative as well as each alternative that was evaluated. Each damage center has a flow-damage relationship, and has a maximum flow that can pass without creating damages to the damageable property, called the start of damages. Each day over the analysis time frame that a stream gage flow was equal to or greater than the start of damages flow for a given damage center can be identified for each alternative considered. Alternatives that create more days over the project life where flows exceed the start of damages can be said to be increasing damages, and would be less desirable than those with equal or fewer total days where flooding exceeds the start of damages. In the following tables, this measurement was termed "Days Flooded."

Another measure of alternative impacts is an estimate of the dollar damages over the project life cycle, generated by interpolating the flows for each day to the flow-damage relationships available, and then generating a grand total over the project life cycle. No estimates of growth within the floodplain are available, and the flow-damage relationships used are current as of their stated price level. No discounting of future benefits was performed to bring the price levels across damage centers in line, and the damages represent nominal damages, in thousands of dollars, at the price level indicated on the flow damage relationship for that damage center.

The "Days Flooded and Marginal Flows" metric was developed to answer the question "Are there days over the project life where flows exceed the start of damages AND are greater than the flows for that day in the No Action alternative?" The number of days and the total damages associated with those particular days was computed, using methods previously described.

The final analysis parameter asks the question "Does the alternative increase damaging flows relative to the No Action alternative?" The answer to that question, yes or no, is the difference of the life cycle damages between each alternative and the No Action alternative. A positive result is "yes."

3.6.1 Example calculation:

The following provides a sample of the calculations used to generate the following tables (**Tables N-3.2, N-3.3, N-3.4)**:

URGWOM daily stream gage flow projects were retrieved to estimate at locations near damage centers identified above for the No Action alternative as well as each alternative that was evaluated over each alternative's life cycle. Corps data used to generate the annual report to Congress of the benefits attributed to completed works uses flow-damage relationships where flows are measured at stream gages. Those daily flows were then used to estimate damages for the damage centers, interpolating between points on the flow-damage relationships. For flows exceeding the zero damage point on the flow-damage relationships, a tally is included in "Days Flooded," indicated that there was flooding that day and the "Interpolated Flood Damages" column is populated with an estimate of damages based on the flow-damage relationship. The "Marginal Flows" column subtracts flows from an alternative from the same daily flow in the No Action condition, and puts a tally in the "Daily Induced Days" column if the project flows exceed the No Action flows for that day, and takes the "Interpolated Flood Damages" for the project condition for every day that project flows are a) exceeding the start of damages condition and b) is greater than the equivalent than the flow in the No Action alternative. The "Days Flooded," "Daily Induced Damages" and "Daily Induced Days" columns are then summed over the project life to get an estimate of cumulative flood impacts over the live of each alternative considered. The final measure of the impact of each alternative is "Induced?" which answers the question, "Do the alternatives generate more total days of flooding over the project life than the No Action alternative?"

Clearly, there are some assumptions that may or may not make sense mathematically. For one, the dollar damages associated with induced flooding is presented here as TOTAL damages, rather than the difference between damages associated with the alternative and the No Action alternative. The public will generally perceive induced flooding as "flooding where there was none before" rather than "flooding where there was none before or a marginal increase in existing flooding." In the sample calculation (**Table N-3.2**), the project has one day of induced flooding, though it is clear that the alternative lessens existing flood events, and the one day where with project flows are greater than No Action flows, the marginal increase in flow is minimal. The with-project flood damages are substantially less than the No Action flood damages, and a significant percentage of those damages are from one "Induced Day."

Table N-3.2 Sample Calculation

Reach 8 - Using Otowi gage		
	Base	Alt. B
Days flooded	5	4
Damages	$8,795.59	$8,734.64
Days flooded AND	N/A	1
Marginal flows >		
		$1,729.73
Induced?		No

3.6.2 Impacts of Alternatives

Each alternative had the desirable impact of reducing flood damages in damage centers. Residual flooding is caused by unregulated drainages flowing into the Rio Grande downstream of existing reservoirs. Generally, and across all damage centers, the number of days that flows exceeded start of damages dropped dramatically from the No Action alternative (**Table N-3.2**), signifying that each alternative considered had substantial flood control benefits. No significant impact occurred in which there were more days of flooding or flood damages greater than the No Action condition.

There were some exceptions to the benefits described above. Along, Belen, NM, Alternatives B-3 and E-3 had increasing damages over the No Action Alternative. The total number of days was small, and varied depending upon which data point was used for the analysis. Flood duration study data was not current for this reach. The Corps is currently studying flood control alternatives for this reach of the Rio Grande.

3.6.3 Impacts of the EIS Alternatives

Under the No Action Alternative, operations of the reservoirs continue as before, and the Upper Rio Grande would be subjected to periodic flood and inundation damages. This flooding would be due to unregulated drainages flowing into the Rio Grande downstream of existing reservoirs. The following tables summarize the calculated impacts of flooding in each section under each alternative (**Table N-3.3 and N-3.4**).

Table N-3.3 Impacts of No Action Alternatives

Using Otowi gage			Days Flooded	Interpolated Flood Damages	Using Otowi gage			Marginal Flows	Interpolated Flood Damages	Daily Induced Damages	Daily Induced Days
Base Conditions			5	$8,795.59	**Alternative B-3**				$7,024.85	$1,729.73	1
Date	**Otowi. Gage Outflow (units—cfs)**				**Date**	**Otowi. Gage Outflow (units—cfs)**					
5/9/2031	10246.65	Yes	1	$1,770.44	5/9/2031	10242.86	Yes	(3.79)	$1,769.14	0	0
5/10/2031	10228.17	Yes	1	1,764.08	5/10/2031	10228.11	Yes	(0.06)	1,764.06	0	0
5/8/2031	10261.27	Yes	1	1,775.47	5/8/2031	10221.88	Yes	(39.39)	1,761.92	0	0
5/11/2031	10128.28	Yes	1	1,729.72	5/11/2031	10128.31	Yes	0.03	1,729.73	$1,729.73	1
5/7/2031	10204.33	Yes	1	1,755.88	5/7/2031	5049.64	No	(5,154.69)	0	0	0

Table N-3.4 Calculated Impacts of Flooding

Northern Section

Reach 4 - Velarde and Lyden, NM

	No Action	Alt. B-3	Alt. D-3	Alt. E-3	Alt. I-1	Alt. I-2	Alt. I-3
Days flooded	20	20	20	20	20	20	20
Damages	$1,711.70	$1,711.70	$1,711.70	$1,711.70	$1,711.70	$1,711.70	$1,711.70
Days flooded AND Marginal flows >	N/A	0	0	0	0	20	20
Damages		$0.00	$0.00	$0.00	$0.00	$1,711.70	$1,711.70
Increased over No Action?		No	No	No	No	No	No

Damages in thousands of dollars

Table N-3.4 (continued) Calculated Impacts of Flooding

Rio Chama Section

Reach 7 - Abiquiu to Española, NM

Agricultural damages >1800 cfs (no flows > 4200 cfs start of damages)

	No Action	Alt. B-3	Alt. D-3	Alt. E-3	Alt. I-1	Alt. I-2	Alt. I-3
Days flooded	1006	341	711	613	987	766	619
Damages	$4,970.61	$1,280.40	$4,090.96	$2,810.05	$4,775.13	$3,560.30	$2,835.59
Days flooded AND Marginal flows >	N/A	6	614	34	957	738	602
Damages		$14.74	$3,686.38	$108.17	$4,718.21	$3,472.53	$2,782.23
Increased over No Action?		No	No	No	No	No	No

Española

Reach 7 - Using Chamita gage - no damage

Reach 8 - Using Otowi gage

	No Action	Alt. B-3	Alt. D-3	Alt. E-3	Alt. I-1	Alt. I-2	Alt. I-3
Days flooded	313	261	279	272	301	283	272
Damages	$202,656.50	$151,776.45	$175,294.00	$162,659.60	$200,740.35	$183,190.41	$166,405.30
Days flooded AND Marginal flows >	N/A	27	169	23	20	21	272
Damages		$14,379.31	$117,795.11	$12,452.09	$10,504.31	$10,142.50	$166,405.30
Increased over No Action?		No	No	No	No	No	No

Damages in thousands of dollars

Table N-3.4 (continued) Calculated Impacts of Flooding

San Acacia Section

Reach 14 - San Acacia to Elephant Butte

	No Action	Alt. B-3	Alt. D-3	Alt. E-3	Alt. I-1	Alt. I-2	Alt. I-3
Days flooded	208	56	6	64	188	139	6
Damages	$4,269,804.74	$1,054,421.02	$53,728.59	$1,462,438.71	$3,228,307.55	$1,431,151.31	$52,707.99
Days flooded AND	N/A	21	0	25	2	139	6
Marginal flows >		0	0	0	0	0	0
Damages		$535,364.17	$0.00	$1,003,512.35	$13,626.17	$1,431,151.31	$52,707.99
Increased over No Action?		No	No	No	No	No	No

Damages in thousands of dollars

Table N-3.4 (continued) Calculated Impacts of Flooding

Central Section

Reach 12 - Corrales, NM

		No Action	Alt. B-3	Alt. D-3	Alt. E-3	Alt. I-1	Alt. I-2	Alt. I-3
Days flooded		121	88	103	102	119	106	97
Damages		$3,111.43	$6,493.30	$690.19	$8,178.36	$784.95	$696.44	$653.63
Days flooded AND		N/A	83	24	99	58	106	97
Marginal flows >								
	Damages		$6,483.88	$208.74	$8,168.59	$365.22	$696.44	$653.63
Increased over No Action?			No	No	No	No	No	No

Reach 12 - Albuquerque, NM - No damages

Reach 12 - Belen, NM

Below Isleta Wastewater Reach

		No Action	Alt. B-3	Alt. D-3	Alt. E-3	Alt. I-1	Alt. I-2	Alt. I-3
Days flooded		0	46	0	52	0	0	0
Damages		$0.00	$35,980.04	$0.00	$53,111.70	$0.00	$0.00	$0.00
Days flooded AND Marginal flows >		N/A	46	0	52	0	0	0
	Damages		$35,980.04	$0.00	$53,111.70	$0.00	$0.00	$0.00
Increased over No Action?			Yes	No	Yes	No	No	No

Central Section

Below Isleta Diversion Reach							
	Base	Alt. B	Alt. D	Alt. E	Alt. I-1	Alt. I-2	Alt. I-3
Days flooded	0	26	0	26	0	0	0
Damages	$0.00	$8,940.83	$0.00	$23,367.13	$0.00	$0.00	$0.00
Days flooded AND Marginal flows >	N/A	26	0	26	0	0	0
Damages		$8,940.83	$0.00	$23,367.13	$0.00	$0.00	$0.00
Increased over No Action?		Yes	No	Yes	No	No	No

Damages in thousands of dollars

Southern Section

Reach 17 - Hudspeth County, TX - No damages or induced damages

Damages in thousands of dollars

Days flooded - Number of days over the scenario where daily flow exceeds the start of damages flow.
Damages - Sum of damages computed where flow exceeds start of damages flow over scenario
Days flooded and marginal flows greater - Number of days and damages where the alternative flow exceeds start of damages AND is greater than equivalent day in No Action condition.
Increased over No Action? Yes/No. Value where Yes — Project damages >Base damages; No — Project damages <— Base damages

4.0 HYDROPOWER

4.1 Introduction

This section of the EIS examines the hydropower production, which is impacted by storage regulation and allocation at various reservoirs in the Rio Grande Basin. These areas are at the Middle Rio Grande Conservancy District's El Vado Reservoir; the Bureau of Reclamation's Elephant Butte Reservoir; and the U.S. Army Corps of Engineers' Abiquiu Reservoir. The first two are located on the Rio Chama, and the latter is on the Rio Grande near the city of Truth or Consequences. Changes in operation will affect the total generation of these plants.

4.2 Historical Power Provision

A net generation of 164,291,220 kilowatt hours (kwh) was recorded at the Elephant Butte Powerplant during 1987. This was an increase of 252% over the 47 year average from 1940 through 1986 of 65,231,128 kwh. The net power generated during 1987 was the second highest amount recorded in any one year during the powerplant's 48 years of operation. The 1986 net generation of 166,340,400 kwh was the record setting net power generation. These resulted from the record reservoir releases occurring in this time period.

El Vado and Abiquiu data has not currently been obtained.

4.3 Potential Impacts

There are two components to hydropower benefits. The first, the capacity benefit is associated with investment costs that would be displaced by the additional hydro generation. The capacity benefits are based on the dependable capacity of the hydro plant and a unit capacity value based on the fixed costs of the most likely thermal alternative. A significant impact would be a material increase or decrease in the capacity benefit.

The second component is the energy benefit. This measures the displaced variable costs and is the cost of energy that would be produced from other generation sources if the hydropower is not available; specifically, the cost of generation from the area powerplants that would most likely provide the replacement generation (or would be displaced by additional hydro generation). These energy costs are primarily fuel costs, along with some variable O&M and transmission costs. Energy benefits are computed as the product of the average annual energy and unit energy value which represents the average cost of replacement generation. A significant impact would be a substantial increase or decrease in the energy benefits provided by an alternative considered.

The hydropower values derived will be used in conjunction with other groups EIS analysis to estimate benefits of each operating plan, including the without project condition. The kilowatts estimated for each operating plan will be multiplied by the value of a hydropower kilowatt. The difference between plans will be measured on the basis of a 5 5/8 percent interest level, current prices, and standard discounting procedures.

Hydropower values on the dams will be computed differently. A previous analysis (1991), which is currently being updated, provides the following information: The El Vado and Abiquiu plants are used primarily to displace thermal energy and are not considered to have dependable capacity. Hence, there will not be any gain or loss in capacity benefits at these projects as a result of changes in reservoir operation. The value of energy from these plants can be estimated by examining the generation resources available to this system and how they will be used to meet loads during 1991 and subsequent years. Following is a list of generation resources at that time. This analysis will be updated to include a more recent list:

- A 32-megawatt share of Public Service of New Mexico's San Juan coal-fired steam plant, which has a total variable cost of 23.5 mill/kwh.
- 10 megawatts from Basin Electric's Laramie River coal-fired steam plant in Wyoming (15 mills/kwh) if San Juan is fully utilized.
- 18 megawatts of gas-fired steam capacity belonging to the Department of Energy-Los Alamos Utilities at 30 mills/kwh.
- 21 megawatts from the Western Area Power Administration (WAPA), which has an annual capacity of 58% and can be load shaped down to a minimum of 6 megawatts (18 mills/kwh).
- 15 megawatts of WAPA peaking capacity at prices of 17 to 30 mills/kwh.
- 8 megawatts of hydroelectric capacity at El Vado and 15 megawatts at Abiquiu with transmission costs of 7.8 mills/kwh and 5.2 mills/kwh for El Vado and Abiquiu respectively.

During the winter months, generation replacing hydropower would be from the San Juan plant, so the value of hydro energy during the November-March period is about 23.5 mills/kwh. During the summer months, San Juan plant electric generation would replace hydroelectric generation also, but as a result of high loads, sometimes more expensive sources must be used, such as WAPA peaking (#5) capacity. This does not occur often, so it is estimated that the weighted average of San Juan and the other generation sources is about 25 mills/kwh during the months of April through September in 1991. An average yearly figure of 25 mills/kwh was used for 1991.

At Elephant Butte, power generation is no longer marketed directly to individual utilities. It is marketed instead as a part of a system which also includes the Bureau of Reclamation's Colorado River projects. Since WAPA contracts the power with Plains Electric and other users for delivery of a portion of the combined system output, the individual utilities would not be directly impacted by changes in the output of Elephant Butte. WAPA would be the entity that would feel these impacts. They would have to purchase replacement power to make up any shortfalls or market for any excess. The value of any hydropower losses could vary, depending upon what type of operationally change is proposed at Elephant Butte. The value of energy might change if operational adjustments require that the daily generating pattern be shifted to more of a base load or to more of a peaking operation than is presently followed.

Elephant Butte has value as a plant providing dependable capacity. This is a measure of its ability to carry peak load and is used to determine how much thermal generating capacity would be required in the power system if the hydro capacity were not available. The dependable capacity accounts for the periodic unavailability of part of the hydro plant's generating capacity due to the variability of hydrologic factors such as streamflow and reservoir elevation. For a hydro project in a thermal based power system such as the Arizona-New Mexico system, dependable capacity would normally be computed as the average capacity available in the peak demand months. An alternative method would be to base it on the capacity available for some specified percentage of the time during the peak demand months. The latter method is used by WAPA in estimating the marketable capacity of the hydro projects in their system. Elephant Butte does contribute 27 megawatts of marketable capacity to the WAPA system, and marketable capacity will be used in this case as a measure of dependable capacity. WAPA bases marketable capacity on the capacity that is available 90 percent of the time during the peak demand months (which in this system are December and January in the winter and July and August in the summer). Some of the proposed reservoir operation plans could result in lower average pool elevations during these periods and hence a loss in dependable capacity. As an interim energy value for the 1991 study, subsequent to discussions with a WAPA representative and local utilities, market prices were used to the next 5 to 10 years (28.83 mills/kwh). After that period, WAPA customers would likely purchase replacement power from a new power plant (51.5 kwh) much of the time. An average of market price and the cost of new combined cycle plant is 40.2 mills/kwh.

4.4 Impact of Future Development

Changes since the 1991 study will have to be quantified and applied to the existing condition analysis as well as each alternative. Future development in this context includes both demand within the region and the resulting impact upon prices. Additionally, future development incorporated competing demands (e.g. Albuquerque's use of San Juan Chama water) which will impact the existing condition as well as each of the alternatives.

4.5 Analysis of Alternatives

The energy benefit of hydro production was computed with flow-energy output relationships pulled directly from the URGWOM model, for Abiquiu, Elephant Butte, and El Vado reservoirs. Annual unit energy values were computed for each of the twenty-five simulated load years. **Table N-4.1** summarizes the unit energy values in $/MWh for each year in the period of analysis, using the FY 2002 interest rate. The values for the future years after 2030 that were not simulated with the model were assumed to be the same as the year 2030 value.

To obtain one levelized unit energy value for use over the period of analysis, the unit energy values for each year were time valued with present worth methods to the year 2005 (the midpoint of the unit Power-On-Line dates for the project). A levelized unit energy value was computed by applying an amortization factor of 6.125 percent (the FY 2002 Federal interest rate for water resources projects) over the assumed 35-year economic project life. **Table N-4.1** also shows the resulting levelized value of 28.40$/MWh.

Table N-4.1 Present Worth and Energy Values

Interest Rate Power-Online-date (Midpoint)	6.125 2005	Current Year Economic Life	2002 35
Year	**Present-Worth Factor**	**Earned Value ($/Mwh)**	**Present-Worth Values Energy Value ($/Mwh)**
2002	1.0000	-----	-----
2003	1.0000	-----	-----
2004	1.0000	-----	-----
2005	0.9423	28.20	26.57
2006	0.8879	28.09	24.94
2007	0.8367	27.98	23.41
2008	0.7884	27.86	21.97
2009	0.7429	27.75	20.62
2010	0.7000	27.64	19.35
2011	0.6596	27.65	18.24
2012	0.6215	27.66	17.19
2013	0.5857	27.66	16.20
2014	0.5519	27.67	15.27
2015	0.5200	27.68	14.69
2016	0.4900	27.89	13.66
2017	0.4617	28.09	12.97
2018	0.4351	28.30	12.31
2019	0.4100	28.5	11.69
2020	0.3863	28.71	11.09
2021	0.3640	28.87	10.51
2022	0.3430	29.04	9.96
2023	0.3232	29.20	9.44
2024	0.3045	29.37	8.94
2025	0.2870	29.53	8.47
2026	0.2704	29.53	7.98
2027	0.2548	29.53	7.52
2028	0.2401	29.53	7.09
2029	0.2262	29.53	6.68
2030	0.2132	29.53	6.30
2031	0.2009	29.53	5.93
2032	0.1893	29.53	5.59
2033	0.1784	29.53	5.27
2034	0.1681	29.53	4.96
2035	0.1584	29.53	4.68
2036	0.1492	29.53	4.41
2037	0.1406	29.53	4.15
2038	0.1325	29.53	3.91
2039	0.1248	29.53	3.69
		TOTAL	**405.35**
	Annualizing Factor @ 6.125, 35 years		**35**
		Annualized Value	**28.37**

4.6 Capacity Value Computation

The Corps' Hydropower Analysis Center (HAC) utilizes a methodology developed by the Federal Energy Regulatory Commission (FERC) to compute capacity values. The capacity value includes allowances for transmission costs, and incorporate capacity value adjustments to account for differences in reliability and operating flexibility between hydropower projects an its thermal alternative.

Hydropower benefits are based on the cost of the most likely thermal alternative that would carry the same increment of load as the proposed hydro project or hydro project modification. Capacity benefits are intended to measure the investment cost of thermal plant capacity that would be deferred by implementation of the hydro plan. Capacity benefits are computed as the product of the dependable capacity of the hydro project and a capacity value, which is based on the unit cost of constructing the most likely thermal alternative.

Utilizing the FERC methodology, unit capacity values for coal, combustion turbine and combined cycle thermal generation was developed for the state of New Mexico. The resulting values were:

Coal	$231.78/kw-yr
Combustion turbine	$ 60.96/kw-yr
Combined Cycle	$111.19/kw-yr

4.6.1 Dependable Capacity

The El Vado and Abiquiu hydropower plants are used to generate power from reservoir releases for irrigation. These releases do not follow any electrical demand pattern and are made as needed for irrigation purposes. On occasion, WAPA will request releases during peak demand periods to displace thermal generation. The generation at these power plants is distributed directly to the City of Los Alamos. Dependable capacity or firm sustain peaking capability is not a factor at these projects.

Elephant Butte has value as a plant providing dependable capacity. This is a measure of its ability to carry peak load and is used to determine how much thermal generating capacity would be required in the power system if the hydro capacity were not available. The dependable capacity accounts for the periodic unavailability of part of the hydro plant's generating capacity due to the variability of hydrologic factors such as streamflow and reservoir elevation. For a hydro project in a thermal-based power system such as the Arizona-New Mexico-Southern Nevada system, dependable capacity would normally be computed as the average capacity available in the peak demand months. An alternative method would be to base it on the capacity available for some specified percentage of the time during the peak demand months. The latter method is used by WAPA in estimating the marketable capacity of the hydro projects in their system. Elephant Butte does contribute 28 MW of marketable capacity to the WAPA system. Therefore marketable capacity will be used in this analysis as a measure of dependable capacity for the Elephant Butte project. WAPA bases marketable capacity on the capacity that is available ninety percent (90%) of the time during the peak demand months, which in the AZ-NM-SNV power system are December and January in the winter and July and August in the summer. Some of the proposed reservoir operation plans could result in lower average pool elevations during these periods and hence a loss in dependable capacity at Elephant Butte.

4.6.2 Impacts Of Alternatives

Generally speaking, each alternative produced additional output at Abiquiu and Elephant Butte reservoirs, and was only differentiated by the amount of additional output produced at each reservoir. The following

(**Table N-4.2**) lists the marginal output and dollar value of that output (using the methodology described above) over the alternative's life cycle.

Table N-4.2 Marginal Output and Dollar Value

	Alternative	Total Marginal Output (MW)	Total Marginal Output (dollars)
Abiquiu	B-3	15,262.68	$445,951.47
	D-3	67,597.33	$1,958,741.32
	E-3	68,824.25	$1,994,402.03
	I-1	63,306.15	$1,833,104.49
	I-2	67,265.65	$1,948,949.33
	I-3	68,884.21	$1,996,196.82
El Vado	B-3	-643.74	$18,693.58
	D-3	-487.65	$14,390.40
	E-3	-379.25	$10,956.43
	I-1	-160.27	$4,601.55
	I-2	-228.83	$6,686.12
	I-3	-271.69	$7,877.05
Elephant Butte	B-3	34,752.41	$1,007,851.48
	D-3	34,897.37	$1,012,102.72
	E-3	34,695.28	$1,006,125.50
	I-1	11,443.08	$324,831.39
	I-2	27,493.37	$794,979.49
	I-3	34,914.73	$1,012,586.43

Each alternative had the effect of lowering energy production at El Vado reservoir, but the additional output at Abiquiu and Elephant Butte more than made up for this loss. Thus, we have a significant, though positive, impact even considering the negative impact of lower power output at El Vado reservoir. On an annual basis, El Vado's losses are somewhere around $300-$1,000 per year, which falls well within the measurement tolerances such that it's possible that there is no impact to El Vado's hydroelectric output from implementing any of the alternatives.

As previously stated, Elephant Butte Reservoir contains the only hydroelectric power plant that provides dependable power. Alternatives that decrease the amount of hydro output at Elephant Butte could make it necessary for power consumers to seek other, more expensive sources of energy, and incurring an opportunity cost for the loss of hydroelectric capacity. Of the alternatives considered, only Alternative I-1 impact's Elephant Butte's dependable power capacity, where the losses are roughly $100 per year ($4,300 over the alternative's life cycle), which falls within measurement tolerances.

4.6.3 Impacts of No Action Alternative

Under the No Action Alternative, operations of the reservoirs continue as before, and the hydroelectric plants at Abiquiu, El Vado, and Elephant Butte Reservoirs continue to provide hydroelectric power. Moreover, Elephant Butte continues to provide dependable power as projected by WAPA.

5.0 River and Reservoir Recreation

5.1 Introduction

Recreation throughout the upper Rio Grande Basin is supported by both reservoirs and rivers. Reservoir recreation occurs as a byproduct of dams built to control floodwaters and sedimentation and to store irrigation waters. Due to congressional action, certain reservoirs along the Rio Grande Corridor also serve wildlife enhancement purposes. The users of these facilities enjoy activities in the water and along the shorelines. Riverside recreation occurs both at developed facilities and in a more dispersed manner along the river banks where there is public access.

Subsequent sections describe recreation opportunities at reservoirs and along the upper Rio Grande and Rio Chama. For each setting, the following conditions are described: the range of recreational activities; the recreational facilities within the area of interest; and visitation to or estimated level of use for specific recreational facilities or locales.

5.2 River Recreation

Several discrete facilities along the river concentrate recreation and a number of activities occur dispersed along the river. **Table N-5.1** summarizes the activities and amenities at developed site or special areas for each reach in the project area.

Table N-5.1 Recreation Sites and Areas along Upper Rio Grande and Rio Chama by Reach[1,]

Reach	Managing entity	Recreation Site/ area	Activities										
			Camping	Hiking	Fishing	Rafting	Kayaking	Canoeing	Picnicking	Swimming	Wildlife	Winter sport	Hunting
1	USFS	Rio Grande NF	√	√	√	√	√	√	√		√	√	√
1	USFWS	Alamosa NWR		√							√		√
2	USFS	San Juan NF	√	√	√	√	√	√	√		√	√	√
3	BLM	Wild Rivers RA	√	√	√	√	√	√	√		√	√	√
3	BLM/ USFS	Rio Grande NW&SR	√	√	√	√	√	√	√		√		√
3	USFS	Carson NF	√	√	√	√	√	√	√		√	√	√
3	BLM	Taos Box (rafting)				√	√	√					
4	BLM	Racecourse (rafting)				√	√	√					
4	BLM	Orilla Verde RA	√	√	√	√	√	√	√		√	√	√
5	USFS	Santa Fe NF	√	√	√	√	√	√	√		√	√	√
5	NM	Heron Lake SP	√	√	√		√	√	√				√
5	BLM/ USFS	Rio Chama NW&SR	√	√	√	√	√	√	√		√	√	√
6	USFS	Santa Fe NF	√	√	√	√	√	√	√		√	√	√
6	NM	El Vado SP, SWA	√	√	√	√	√	√	√		√	√	√

Reach	Managing entity	Recreation Site/ area	Activities										
			Camping	Hiking	Fishing	Rafting	Kayaking	Canoeing	Picnicking	Swimming	Wildlife	Winter sport	Hunting
6	USFS	Santa Fe NF	√	√	√	√	√	√	√		√	√	√
7	USFS	Chama River Canyon Wilderness	√	√	√	√					√	√	√
7	COE	Abiquiu Lake	√	√	√		√	√	√	√	√	√	√
7	USFS	Santa Fe NF	√	√	√	√	√	√	√		√	√	√
7	USFS	Carson NF	√	√	√	√	√	√	√		√	√	√
9	USFS	Santa Fe NF	√	√	√	√	√	√	√		√	√	√
9	NPS	Bandalier NM	√	√					√		√		
9	NPS	Bandalier Wilderness	√	√					√		√		
9	COE	Cochiti Reservoir	√	√	√		√	√	√	√	√	√	√
10	NM	Coronado State Monument			√				√		√		
12	NM	RG Nature Center (SP)		√							√		
13	NM	La Joya Wildlife refuge									√		√
13	NM	Bernardo Wildlife Refuge									√		√
13	NM	Casa Colorada Wildlife Refuge									√		√
13	USFWS	Sevilleta NWR									√		√
14	USFWS	Bosque del Apache NWR/Wilderness		√					√		√		√
14	NM	Elephant Butte SP	√	√	√		√	√	√	√	√	√	√
15		Caballo Lake SP	√	√	√		√	√	√	√	√	√	√
16	NM	Leasburg SP	√	√	√				√		√		
16	NM	Percha Dam SP	√	√	√				√		√		

Notes: 1. Does not include facilities on tribal and pueblo lands.
2. Includes facilities and public recreational areas directly alongside river or reservoirs.

5.2.1 Northern Section–Colorado/Northern New Mexico (River Reach 1 through 4)

General Recreation.—Spanning seven counties, two States, and several tributaries, the northern section of the Rio Grande, reaches 1 through 4, offers pristine and unrestricted territories. The waters of the northern section harbor local and nationally desired recreational opportunities. Water activities such as rafting, kayaking, and canoeing (known generically as "float boating") dominate the river usage of this area. Swimming and fishing also occur along this section of the river at various locations. Adjacent to the river, recreation includes camping at more than 20 public and private campgrounds, hiking along miles of scenic trails, and wildlife viewing from numerous locations such as the Alamosa National Wildlife Refuge (NWR).

In Reach 3, 64 miles of the Rio Grande have Wild and Scenic River designation for both wild values (along 48 miles) and scenic value along 12 miles. This stretch provides outstanding opportunities for pristine river experiences (BLM 2000).

Several developed recreational facilities in along Reach 4 (**Table N-5.1**) provide amenities for camping, hiking, and picnicking. Also, the wildlife and fisheries resources provide recreational experiences such as wildlife viewing, hunting, and fishing.

Rafting—River rafting and kayaking provide the bulk of water-based recreation use during the spring and summer when there are sufficient flows. High flow rates for the northern section typically fluctuate, occurring in the spring when the winter snow pack melts. When flows are high, the rafting season tends to extend longer into the early summer. Low flow rates in spring and summer in the northern basin (below 200 cfs) hinder river recreation and affect local businesses related to this market (Sundin 2002 a,b).

About 50,000 people use the Rio Grande for kayaking and rafting per year (mostly in reach 4). Popular rafting segments include the Taos Box and the Race Course. The Taos Box (16 miles north of Taos) receives about 10,000 visitors annually, typically from May through June. A minimum flow of 500 cfs is needed for float boating; when the flow exceeds 800 cfs, people flock to the area (Sundin 2002 a,b).

In the Race Course (5 mile south of Pilar), the rapids are less steep so boaters can run on lower water levels such as 150 cfs; however, this is not the optimum float level. This section is less challenging and attracts a higher number of vacationers, families and inexperienced rafters. About 30,000 visitors use this area annually. At low water (150 cfs), the river is floated for its scenic value. May through June is usually the best time for floating this segment of the river. However, depending on the water levels, visitor use will also go into July and August. The remaining 10,000 visitors use stretches of the Rio Grande farther south.

BLM controls the number of boaters using the river, to maintain the river corridor’s primitive character in conformance with its Wild designation (Taos Box) and Scenic designation (Race course portion). Float boating usage is based on reports from commercial outfitters and BLM records. Outfitters pay a per person fee to BLM for the use of the river. Approximately 80 percent of rafters/kayakers use a commercial outfitter. Approximately 20 percent are private parties that register at put-in points. In addition, BLM staff count visitors on various days. Due to drought conditions during the summer of 2001 river flows plunged to flow rates below 200 cfs. In 2002, fires in the surrounding forests were the cause for closure and lack of access for rafting (Sundin 2002a).

River Fishing—Fishing on the northern section of the Rio Grande occurs year round but the best months for the upper Rio Grande are generally September through November. Above the confluence of the Red River, fishing is of high quality, and generally for advanced skill-level anglers. Cutbow, rainbow, and brown trout are the primary catch. Upstream from Pilar, in the vicinity of Pilar State Park and Red River (Taos Junction bridge), 15,000 anglers and 35,000 angler days were recorded for 2000/2001 (Hansen 2003a), down somewhat from 34,000 angler days recorded above Pilar in 1998/1999 surveys (NMDGF 2000). Catchable-sized rainbow trout are stocked in the river below Pilar. About 15,000 angler days were recorded in 1998/1999 for the portion south of Pilar to Cochiti (Hansen 2003a). Most portions of the river below Pilar flow through pueblos in this section, and angler days are not recorded for this stretch of the river, so the total number of angler days is likely higher. Several lakes in the pueblos are popular for fishing. Tribal areas define their own fishing regulations. Favored access points are Pilar State

Park and trails leading down to Red River and the Rio Grand Wild and Scenic River, and Taos Junction Bridge (Hansen 2003b).

5.2.2 Rio Chama section–(Reaches 5 through 9)

General Recreation.—Reaches 5 through 9 occur along the Rio Chama from El Vado Reservoir to the confluence with the Rio Grande at Española and along the main stem down to Cochiti Reservoir in north central New Mexico. Fishing, rafting, hunting and preservation of wild and scenic qualities constitute the dominant use of the northern portion of the Rio Chama. Miles of hiking trails, several camping facilities, good wildlife viewing, swimming, and scenic quality support river recreation.

On the upstream side of El Vado Lake, the Rio Chama Wildlife and Fishing area has trails and campsites (NMDGF 2004). The portion of the Rio Chama between El Vado and Abiquiu is co-managed by the Forest Service and BLM. This 32-mile stretch is designated Wild and Scenic and allows for multiple day trips, unlike the stretches on the Rio Grande that are primarily day trips. The primary put-in is at Cooper's Ranch just below El Vado dam. In the surrounding area, designated as Wilderness by the Forest Service, visitors are able to experience primitive wilderness where no motorized vehicles (e.g., ATVs, OHVs) are allowed. The last 8 miles of river above Abiquiu Reservoir is not designated Wild and Scenic and can be run as day trip. For this stretch, Chavez canyon put-in point, located south of the Christ in the Desert Monastery, is popular and has developed camping. Only 2,000 to 3,000 people per year float the Wild and Scenic River section of the Rio Chama. The Chavez canyon day use area receives another 2,000 to 3,000 visitors/rafters each year (Sundin 2002a).

Below the confluence, Bandalier National Monument has hiking trails through scenic canyons down to the river. Float boating is popular from the bridge at the Otowi gage down to Cochiti reservoir during the spring runoff and summer.

Rafting.—The BLM has a lottery system for rafting permits and there are only 250 launch permits for the Rio Chama each year. BLM receives over 10 times that number of applications (Sundin 2002a), attesting to the popularity and demand for rafting opportunities. There are two "float" seasons on the River Chama: the runoff season from May 1 through mid-June and the irrigation season from mid-July through August. The slack time in between the seasons usually allows a predictable flow (through informal agreements between operators and contractors) of 1,000 cfs from Friday through Sunday and 500 cfs Sunday evening through Thursday. Visitors cannot raft the Rio Chama at 100 cfs—the minimum required is 250 cfs. At this water level, kayakers and canoes can float the rivers, but rafters cannot because a minimum of 500 cfs is required for rafting, and 1,000 cfs is better (Sundin 2002).

Fishing.—Total angler days recorded for the Rio Chama above El Vado in 1998/1999 were 36,000, about 24,000 between El Vado and Abiquiu Reservoir and 14,000 below Abiquiu to the confluence with the Rio Grande (NMDGF 2000). There was an increase during the 2000/2001 season with 36,000 angler days recorded between El Vado and Abiquiu (Hansen 2003a). The primary fish are rainbow trout (stocked) and brown trout (wild), and spring and summer are the main fishing seasons. Fishing conditions are impaired when flows fall below 150 cfs and rise above 800 cfs. Below Abiquiu, the quality of fishing declines with high flows and improves with lower flows, with the best conditions when the flow is less than 300 cfs. Good spring flows helps scour habitat (mimicking the natural hydrograph) and are best for wild species (Hansen 2003a). Popular access points are the tailwater area around Abiquiu dam and along the river near Christ in the Desert Monastery above Abiquiu Lake (Hansen 2003b).

5.2.3 Middle Section–Cochiti to Elephant Butte (Reaches 10 through 14)

The middle section of the Rio Grande includes reaches 10 through 14. This diverse portion of the river has natural, urban, and agricultural areas. River recreation in this region competes with reservoirs, municipalities, and agriculture use of adjacent land. River flows in the middle section are controlled through seasonal demands for irrigation, municipal and industrial use, as well as demands to meet State, national, and international policies.

General Recreation.—Recreational use in the middle section concentrates around the reservoirs and New Mexico State parks that receive approximately 5 million visitors annually. More than 37 percent of these visitors recreate at Cochiti and Elephant Butte Reservoirs (NMEMNRD 2001). Water sports such as fishing, swimming, and motorized watercraft recreation are the main attractions at reservoirs. River recreation is limited to activities such as relaxed floats down the river, wildlife viewing, and hiking the miles of trails adjacent to the rivers of the Middle Basin, particularly in the Rio Grande Valley State Park and Nature Center that extends along the river in Albuquerque (reach 12). The river is also an essential feature for several wildlife refuges in the middle section (see Appendix N2 and **Table N-5.1**). The Bosque del Apache is particularly popular and valued by both in-State and out-of-State visitors, and renowned for the daily spectacle of geese and waterfowl leaving and returning to roost each day. The BDA has averaged almost 150,000 visits annually, mostly between October and March (USFWS 2004). Other managed refuges along the river have more emphasis on wildlife programs, with recreational access for wildlife viewing, some duck hunting, and fishing, being secondary. Waterfowl hunting is also popular at Bosque del Apache, La Joya and Bernardo Wildlife Areas, and along the LFCC.

Fishing.—Fishing is popular just below the Cochiti outfall. Angler days recorded during the 1998/1999 season were about 22,000 between Cochiti and I-40 in Albuquerque, and 40,000 in 2000/2001. South of I-40 to Elephant Butte, 32,000 angler days were recorded for during 1998/1999 season. In general, high quantity releases from the reservoir affect fishing downstream in a beneficial manner, low-quantity releases from the reservoir do not enhance fishing quality. Fishing conditions are best when flows below Cochiti are between 500 and 2,000 cfs (NMDGF 2000, Hansen 2003a). Fishing is optimal in Fall, winter and spring. The primary species are rainbow trout (stocked below the dam, but not in summer), largemouth bass, and channel catfish. A popular fishing location below the Cochiti outfall is being closed and the location for a new site at the reservoir is being considered by the COE. Some fishing takes place along the larger drains and ditches running through Bernalillo and Albuquerue, at Coronado State Monument, at Conservancy Park (Hansen 2003b). While convenient, these waters do not provide the high quality fishing opportunities found further north. Fishing is less prominent in Reaches 13 and 14 below Los Lunas (Hansen 2003b).

5.2.4 Southern Section–Southern New Mexico/Texas (Reaches 15 through 17)

This section follows the Rio Grande through southern New Mexico and into northwestern Texas. The river supports numerous types of wildlife, miles of hiking trail, and several camping facilities, but agricultural and municipal use is dominant. Flow rates in the Southern Basin are generally lower than in the Northern Basin due to local irrigation demands that deplete the river for water. Waters of the southern basin are generally more turbid than in the faster flowing waters of the Northern and Middle Basin.

Fishing in the Rio Grande south of Elephant Butte to Caballo is popular, with 51,000 angler days recorded for 1998/1999. South of Caballo Lake, 35,000 angler days were recorded. It should be noted that the majority of fishing takes place at the lakes themselves, with about 400,000 angler days counted for these lakes (combined). State Park facilities are located at Leasburg Dam and Caballo reservoir. In Texas, most of the riverside land is privately owned. Therefore public access for fishing is limited.

5.2.5 Fishing Statewide

Overall, fishing is one of the main recreational opportunities afforded by the Rio Grande. New Mexico is primarily a trout-fishing State. Other popular fish include bass, kokanee salmon, lake trout, walleye, and pike. Conditions sought for quality fishing include lack of fishing pressure (from other anglers), scenery, solitude, accessibility, size, and abundance of fish. The upper reaches provide cold-water fishing, and the lower reaches provide warm-water fishing. NMDGF recorded a total of almost 3.7 million-angler days during 1998/1999 for the entire State of New Mexico, of which almost 1 million (26 percent) were in the project area. The trend over the last decade shows a general increase in fishing.

5.2.6 River Recreation and the Economy

River recreation is important for the economy and many small businesses in Northern Basin area, particularly complementing the off-ski season. The economy of surrounding communities relies heavily on recreation-related income, employment, and other factors (Sundin 2002b). According to a study prepared in 1994 on the economic impact of river recreation in northern New Mexico, about 85 percent of rafters come from out-of-State (U of AZ 1994). In terms of local business, the spring/summer season for rafting complements the ski industry business that takes over during the winter months.

5.2.7 Reservoir Recreation

This section describes recreation at eight reservoirs (**Table N-5.2 and N-5.3**) within the area of interest. **Tables N-5.2 and N-5.3** provide information about activities and physical amenities at reservoirs and **Table N-5.4** summarizes visitation between 1997 and 2001.

Table N-5.2 Reservoir Recreation resources of the Upper Rio Grande Basin

Reservoir site	Owner	Recreation Operator	Recreational Activities									
			Camping	Picnicking	Hiking	Wildlife viewing	Biking	Hunting	Fishing	Swimming	Boating[1]	Winter sports[2]
Platoro	USBR	State of NM	X	X	X	X	X	X	X	X	X	X
Heron Lake	USBR	State of NM	X	X	X	X			X		X	X
El Vado	MRGCD	State of NM	X	X	X	X			X		X	
Abiquiu	COE	COE	X	X	X	X			X		X	
Cochiti	COE	COE	X	X	X	X		X	X	X	X	
Jemez	COE	Jemez pueblo		X		X						
Elephant Butte	USBR	State of NM	X	X	X	X	X		X	X	X	X

Caballo Dam	USBR	State of NM	X	X	X	X			X	X	X	X

Sources: Casados 2001, Dunlap 2001, USCOE 2001
Notes:
[1]Boating includes rafting, kayaking, canoeing, and motor boating.
[2] Winter sports include snowmobiling, skiing, sledding, etc.

Table N-5.3 Reservoir recreation facilities and key elevations for the Upper Rio Grande Basin

Reservoir site	Recreational water levels[1] (low/optimal/high (feet)	Visitor center	Camp sites	Restrooms	Showers	Parking lots	Shelters	Trails	Boat ramps	Marinas
Platoro	Unk/10,034/10,042	N	N	N	N	Y	N	Y	1	N
Heron Lake	7,145/7,186/7,191	Y	284	Y	Y	Y	1	Y	2	Y
El Vado	6,902/6,909	Y	54	Y	Y	Y	2	N	1	N
Abiquiu	6,202/6,222/	Y	66	Y	Y	Y	1	Y	1	N
Cochiti	5,317/5,340/5,370	Y	146	Y	Y	Y	Y	Y	2	Y
Jemez	/5,271/	N	N	Y	N	Y	1	N	N	N
Elephant Butte	4,400//4,700	Y	111	Y	Y	Y	10	Y	3	3
Caballo Dam	4,161//4,182	Y	200	Y	Y	Y	3	Y	2	N

Sources: Casados 2001, Dunlap 2001, USCOE 2001
Notes:

Table N-5.4 Visitation to Reservoir Facilities

Reservoir site	Annual visitation				
	1997	1998	1999	2000	2001
Heron[1]	153,841	166,787	179,266		
El Vado[1]	45,367	46,998	43,478		
Heron/El Vado [2]	169,962	227,227	213,785	241,996	221,590
Abiquiu[1]	76,491	97,426	87,142	121,833	Incomplete
Cochiti Reservoir[1]	315,717	319,249	269,629	322,781[3]	336,878[3]
Elephant Butte Reservoir[1]	1,754,055	1,804,833	1,620,716	1,759,813	1,466,021
Caballo Reservoir[1]	411,034	345,457	326,791	247,731	211,350
NM State Parks	5,206,397	4,953,418	4,677,205	4,195,149	3,982,097
NM National Parks/ Monuments	2,253,186	2,076,080	2,015,613	1,766,079	1,843,650

Sources: Casados 2001, NMEMNRD 2001, USCOE 2001
Notes:

5.2.8 Platoro Reservoir

Platoro Dam and Reservoir are located on the Conejos River approximately 1 mile north of the town of Platoro, in Costilla County, Colorado. The facility is owned by Reclamation and operated by the Conejos Water Conservancy District for the purpose of flood control, irrigation storage, recreation, and fish and wildlife enhancement.

Recreational usage at Platoro is limited due to difficult access and the quality of facilities. Despite the challenges, visitors enjoy picnicking, hiking, wildlife viewing, fishing, and other activities (**Tables N-5.2 and N-5.3**).

Water levels at Platoro Reservoir create minor concern in terms of recreational management (Hong 2001). Only one boat launch is available at the reservoir. Under low-water conditions, boat ramp access becomes more difficult than it already is. Below the reservoir, high quantity water releases reduce fishing quality due to the increase in turbidity. On the other extreme, low-water flows during the wintering months create conditions below the threshold level for fish life; winter fish kills have resulted in recent years.

Fishing is the main attraction at Platoro. Therefore, maintaining fishing quality is the primary concern for the Platoro staff. Fish stocking efforts have historically supplemented the cold water fishery that Platoro harbors. Modern outbreaks of whirling disease have resulted in the reduction of stocking efforts. With the decline in fishing quality there has been a decline in visitation and usage. Peak season for recreation at Platoro is June 1 through October 1. Visitation at Platoro Reservoir is not monitored.

5.2.9 Heron Reservoir

Heron Dam and Reservoir (Heron Lake) is located on the Rio Chama in Rio Arriba County, about 180 miles north of Albuquerque. Recreational activities at Heron Lake State Park include camping, picnicking, fishing, boating (limited to no-wake speeds), sailing, hiking, wildlife viewing, and winter activities (non-motorized). These activities are supported by a variety of structures such as campsites, boat docks, and visitor center distributed throughout the complex (**Tables N-5.2 and N-5.3**).

Heron Lake has two boat docks. Recent low-water elevations of 7,136 feet have created access problems to these boat docks. One boat dock becomes inoperable at 7,145 (and is currently not in operation). The other remains open throughout the year. To accommodate dynamic water levels, park personnel routinely move equipment such as boat docks (Casados 2001). Although lower water levels expose hazards, fishing, boating, and other water activities continue.

The facility operates year-round. However, certain campgrounds close in the winter when visitation is low (around December 1). The higher-use campgrounds remain open throughout the year. Highest-use season is between Memorial and Labor days.

The primary recreational activities on the lake are fishing and sailing. Since El Vado and Heron Lake are close geographically, visitation data is counted together. However, the two facilities provide different types of recreation opportunities. Sailboat use is quite heavy at Heron. No jet skis or speedboats are allowed there. At El Vado Dam, power boating is allowed. Visitors often spend time at each reservoir during a weekend to participate in different activities.

In 2000/2001, 27,000 anglers and 110,000 angler days were recorded for Heron Lake (Hansen 2003a). The primary species are kokonee salmon and rainbow trout (both stocked), and lake trout. Fall drawdowns are detrimental for natural reproduction of lake trout and spawning of stocked kokonee salmon (Hansen 2003a). Water levels during November and December 2002 limited access. Drawdowns lower than the boat ramp affect fishing access.

Visitation at Heron Lake is monitored through staff observations and visitor receipts. Table N-5-3 shows the visitor use of Heron and El Vado Reservoirs compared to that of New Mexico State Parks, National Monuments, and Parks. Over the last three years Heron and El Vado reservoirs received an average of 225,790 visitors annually with the primary focus of visits being camping. This year visitation use is down by 20 to 25 percent. This is attributed to low water levels and fire restrictions (Casados 2001). An estimated 60 percent of visitors come from within New Mexico and 40 percent come from out of State (primarily Oklahoma and Texas). Most in-State visitors come from Albuquerque (Casados 2001).

5.2.10 El Vado Reservoir

Recreation at El Vado reservoir is managed by the New Mexico State Parks Divison. Recreation at El Vado Lake consists of, but is not limited to, camping, fishing, picnicking, boating, and wildlife viewing. El Vado has campgrounds, boat launching facilities, and other structures to support recreation (**Tables N-5.2 and N-5.3**). Visitation numbers at El Vado are combined with those of Heron Lake (**Table N-5.4**). Because power boating and motorized recreation activities are permitted here, this lake is popular. Most visitors camp during their visit.

5.2.11 Abiquiu Reservoir

Abiquiu Dam and Reservoir are located in Rio Arriba County, New Mexico, on the Rio Chama, 32 river miles above the confluence with the Rio Grande. The storage of SJ-C water has maintained the reservoir at higher elevations that favor recreation. Abiquiu Reservoir provides boating, fishing, camping, picnicking, hiking, and wildlife viewing. These activities occur at developed recreation areas along the lake (**Tables N-5.2 and N-5.3**). The popularity of the lake is augmented by the presence of other points of interest in the area, including the Georgia O'Keefe House, Echo Amphitheater, Monastery of Christ in the Desert, Dar al Islam (a Muslim Mosque), and Poshuouinge Ruins. Visitation for Abiquiu was determined through the use of vehicle counters and the Visitation Estimation and Reporting System (VERS). **Table N-5.4** shows visitation use of Abiquiu Reservoir compared to that of New Mexico State Parks, National Parks, and Monuments. Over the four years from 1997 through 2000, the average annual visitation was 95,723. The primary recreation activities were fishing, camping, and boating.

Water levels at Abiquiu Reservoir fluctuate seasonally. These changes affect the overall facility operations. Dynamic water levels at the reservoir are known to create increased costs related to the erosion of roads and parking lots, as well as the need for riprap, base coarse, gravel, and dock extensions. Releases from the reservoir that create flows greater than 600 cfs hinder fishing below the dam (Dunlap 2001).

At Abiquiu Reservoir, the optimal water level for lake and facility usage is 6,222 mean sea level (msl). If the water level falls below 6,217 msl, the high-water boat ramp becomes inaccessible. At 6,202 msl, the low-water boat ramp is off the concrete, which makes access difficult. The low-water parking lot floods at water levels at or above 6,225 msl (Dunlap 2001).

Fishing at Abiquiu and the Rio Chama River below the dam is very popular and fairly productive any month of the year. Several years ago Abiquiu Reservoir was considered a warm water fishery with crappie being the most often-caught species. Over the last decade, however, the lake has gone through a transformation as more water is being stored at Abiquiu than in years past. Water at Abiquiu is now much deeper and therefore much colder. This has changed the reservoir from a warm-water fishery into a predominantly cold-water fishery, although some warm-water species are still caught (Corps 1999).

In 2000/2001, 15,000 anglers and 37,000 angler days were recorded. Kokonee salmon, walleye, and rainbow trout are stocked. Smallmouth bass and white crappie occur naturally, and are negatively affected by late May-June drawdowns (Hansen 2003a).

5.2.12 Cochiti Reservoir

Cochiti Dam and Reservoir are located in Sandoval County, New Mexico on the Pueblo de Cochiti lands, approximately 50 miles north of Albuquerque, New Mexico. Recreation at Cochiti Reservoir is supported by the Cochiti Recreation Area on the west side of the reservoir, Tetilla Peak Recreation Area on the east side of the reservoir, the Al Black Recreation Area and the Visitor Center. Visitors participate in an array of activities throughout the complex (**Tables N-5.2 and N-5.3**). Fishing and sailing are the main recreational activities of Cochiti Reservoir.

Visitation at Cochiti Reservoir is monitored by traffic counters and the VERS program. **Table N-5.4** shows visitation use of Cochiti Reservoir compared to New Mexico State Parks, National Parks, and Monuments. Over the 4 years from 1997 through 2000, the average annual visitation was 387,539. The primary recreation activities were fishing and boating.

The high-water mark at Cochiti Reservoir is 5,370 msl. Water levels of this magnitude inundate project boat ramps, parking lots, beaches, and the day-use area. The low-water mark for Cochiti is 5,317 msl. This elevation occurs at the very end of the Cochiti boat ramp. Levels below the low-water mark make use of the boat ramp difficult. The optimal water level for most recreational activities at Cochiti is 5,340 msl (USCOE 2001).

Dynamic water levels are common at Cochiti due to seasonal demands for the storage of water and water releases. High-quantity releases from the reservoir affect fishing downstream in a beneficial manner, low-quantity releases from the reservoir do not enhance fishing quality. Operating costs for Cochiti increase with extreme water level fluctuations due to repairs, increased labor requirements, and clean-up activities.

In 2000/2001, 23,000 anglers and 80,000 angler days were logged for Cochiti reservoir. Cochiti is not considered a great spot for fishing (Hansen 2003a). Primary species in the lake are largemouth bass, northern pike, white crappie, and channel catfish, with spring and fall the heaviest fishing seasons. The hydrology of the reservoir has little effect on fishery.

5.2.13 Jemez Reservoir

Jemez Canyon Dam and Reservoir are located in Sandoval County, New Mexico within the confines of Santa Ana Pueblo. The dam and storage space are owned and operated by the Corps for flood and sediment control. However, the use of the lake and surrounding land is owned and controlled by the Pueblo.

Recreational use of the facilities at Jemez Reservoir is limited due to the surrounding land ownership. Currently, no water is being stored in the reservoir; therefore, no water-based activities take place there. In the past, use of the water has been limited to Tribal members. Public recreational use consists of day picnicking only with no access to the water. An overlook facility (**Tables N-5.2 and N-5.3**) is popular for viewing the scenic lake. Without access to the water, general public visitation is low compared to other reservoirs. Tribal visitation numbers are not known.

5.2.14 Elephant Butte Reservoir

Elephant Butte Dam and Reservoir are located 125 miles north of El Paso, TX in Sierra County, New Mexico (at the end of reach 14). Elephant Butte Reservoir is the largest and most-visited recreation area administered by Nm State Parks Divison. Combined with Caballo Reservoir, it offers a wide range of year-round recreational opportunities and draws visitors from New Mexico and surrounding States. During winter, the mild climate provides a haven for campers and anglers from the colder northern climates. In spring, summer, and fall, Elephant Butte and Caballo Reservoirs teem with recreational activities including fishing, developed, and dispersed camping, boating, swimming, use of personal water craft, hiking, biking, wildlife viewing, and hunting. Recreation opportunities and facilities that support these activities are shown in **Tables N-5.2 and N-5.3**.

Visitation for Elephant Butte was determined through the use of vehicle counters and the VERS. Approximately 75 percent of the 1.5 million-plus visits occur between April and September. New Mexico State Park personnel estimate that on peak weekends, such as Memorial Day, between 80,000 and 100,000 persons visit the park (USDOI, BLM 1999). As **Table N-5.4** shows, Elephant Butte provides over a third of the total visitor use to New Mexico State Parks. Average annual visitor use from 1997 through 2000 was about 1,735,000 visitors.

Elephant Butte Reservoir is full at 2.1 million acre-feet of water, with 1.6 million acre-feet the optimal water level, according to reservoir officials. Dynamic water levels affect recreational management of the facilities and increase operational costs. High-water levels reduce the area of land usable by visitors. As a result, consolidation problems arise, and Park officials have noted increased incidents of conflict among visitors due to crowding. Also, portable facilities have to be relocated to accommodate the higher water levels. During low-water conditions, accessibility becomes challenging and park officials are forced to move portable facilities. Lower water levels increase debris exposure in the lake (which can be unsafe for boaters and skiers). Also, lower levels expose debris along the shoreline, which needs to be cleaned up for aesthetic reasons.

Fishing is also a main recreation activity, offering the opportunity to catch striped bass, white bass, crappie, largemouth bass, walleye, and catfish. In 2000/2001, 40,000 to 80,000 anglers and 250,000 to 350,000 angler days were estimated at the reservoir. There are mostly wild fish in the lake (Hansen 2003a). White bass is the primary catch, followed by smallmouth bass, and catfish. Striped bass are stocked. Spring and fall are the primary seasons. Drawdowns in April through June (for irrigators in the south valley) are detrimental for fish reproduction. As the lake goes down, there has been a steady decline in fishing, due both to poorer access and less reproduction.

5.2.15 Caballo Reservoir

Caballo Dam and Reservoir are located 17 miles south of Truth or Consequences in Sierra County, New Mexico, 25 miles downstream from Elephant Butte Dam. The reservoir supports numerous activities such as camping, fishing, hiking, swimming, sailing, water-skiing, picnicking, and wildlife viewing. Caballo Reservoir accommodates these activities through multiple facilities located on site (**Tables N-5.2 and N-5.3**). Combined with Elephant Butte, Caballo offers year-round recreation opportunities. Water fluctuations at Caballo Reservoir make camping difficult to manage. At high-water levels, some of the existing dispersed camping areas are flooded. Often people do not know where the water will be and what camping areas will be accessible from one week to the next (USDOI, BLM 1999). Fishing, motor boating, and swimming are the most popular recreation activities at Caballo Reservoir (USDOI, BLM 1999).

Visitation for Caballo was determined through the use of vehicle counters and the VERS. **Table N-5.4** shows reservoir visitor use compared to that of New Mexico State Parks and National Monuments and Parks. The average annual visitor use from 1997 through 2000 was 332,753 visits. According to the Elephant Butte and Caballo Resource Management Plan EIS (1999), the fluctuation in visitor use can be correlated directly with water level fluctuations in the reservoirs, which have a direct effect on access to the shoreline and shoreline camping (USDOI, BLM 1999).

Reservoir levels are operated at 25,000-80,000 acre-feet in accordance with the Caballo management plan. If the water level drops below 15,000 acre-feet, then boat ramp access becomes impaired. The highest water level recorded at Caballo Reservoir is 200,088 acre-feet. At high-water levels, parking lots and other facilities become inundated. Dynamic water levels due to seasonal demands affect recreational management of Caballo Reservoir. Reservoir staff have documented difficulty accessing boat launching sites and fluctuations in fishing quality due to the alternating water levels.

If the water level drops below 15,000 acre-feet, then boat ramp access becomes impaired. The highest water level recorded at Caballo Reservoir is 200,088 acre-feet. At high-water levels, parking lots and other facilities become inundated. Dynamic water levels due to seasonal demands affect recreational management of Caballo Reservoir. Reservoir staff has documented difficulty accessing boat launching sites and fluctuations in fishing quality due to the alternating water levels.

5.3 Recreation Impacts

Many factors affect recreational opportunities and experiences. A key measure of impacts on recreation is changes in visitation. However, it is difficult to estimate changes in visitation because it is influenced by so many factors. For example, weather on holiday weekends, availability of alternate sites and preferable sites for similar activities, gas prices, fire hazard restrictions and forest closures, previous experiences, population growth, method of counting, and accuracy, and staffing and condition of facilities are some factors that may affect visitation levels. It is difficult to attribute changes in visitation levels or trends specifically to water operation-driven factors such as reservoir elevations and in-stream flows. However, this analysis uses selected measurable criteria to provide comparisons between the alternatives. These criteria are indicators of conditions that may favor or inhibit recreation at reservoirs or along the river.

The analysis of water-related recreation considered the following key issues and concerns:

- Maintaining flows for rafting/kayaking;
- Maintaining conditions for quality fishing;
- Inundation of developed recreation sites;
- Reservoir elevations allow access for boating;
- Inundation of facilities or muddy shorelines;
- Affects of reservoir drawdowns on sport and native fishery; and
- Reservoir water levels that are safe for navigation and water-based activities.

The analyses use the following measurable criteria:

- Flows suitable for rafting (preferred minimum flow is >500 cfs in Reach 6)
- Flows suitable quality fishing: for anglers and fish reproduction
- Inundation of key access and recreation sites along the river

- Inundation of key facilities at reservoirs
- Low water levels at reservoirs that limit boat access

Assumptions and Limitations:

- Northern section not evaluated as no operational effects
- Below Elephant Butte not evaluated as not modeled; therefore, comparative effects data
- Reach 11 not evaluated as there would be no operational effects above Jemez Canyon, and agricultural lands area below the dam overlap with Reach 12 below Cochiti (and are therefore represented in the analysis).
- Under the No Action, reservoir and river-related recreation would continue throughout the Basin. Water-based recreation will continue to provide an important opportunity in an environment where water and moisture is limited. These activities will continue to respond to direct factors, such as reservoir levels and river flows, but other dominating factors such as trends in preferred recreational activities, population growth, weather on holidays, availability of alternate places to recreate, gas prices, adequacy of facilities, and forest fires. These factors may either promote or lower visitation in any given season, year, or decade. Because of this variability, the analysis focuses of qualitative effects rather than estimating changes in visitation or use.

Tables in the following section summarize data for several criteria to indicate the relative performance of the alternatives in providing suitable conditions for specific recreational activities. Criteria selected are representative and generally only apply to some reaches or facilities. These measures are comparative indicators to assess the degree to which the alternatives may promote suitable conditions for recreation.

5.4 Reservoir Recreation

Table N-5.5 summarizes number of days over 40 years when water levels are unsuitable for access to facilities based on indicative elevations provided by reservoir personnel. Current management of facilities The No Action is somewhat less beneficial than the other alternatives. Current operations and visitation reflects the challenges from recent lower lake levels. For example, at Elephant Butte, the most visited lake in the Basin, new boat ramps have been added to provide access for boats as lake levels change.

Table N-5.5 Access for Water-based Activities at Reservoirs

Alternative	% days lake elevation impairs access			
	Heron Lake[1]	Abiquiu[1]	Cochiti[1]	Elephant Butte[1]
No Action	29%	88%	1%	12%
B-3	31%	65%	<1%	0%
D-3	29%	70%	<1%	0%
E-3	29%	69%	<1%	0%
I-1	29%	86%	<1%	6%
I-2	29%	78%	<1%	<1%
I-3	29%	69%	<1%	0%

Source: derived from URGWOM (40-year, daily reservoir elevation)
Best
Worst
Notes:
1. The following critical (unsuitable) elevations are used:
Heron Lake: <7,136 feet (Casados 2002)
Abiquiu reservoir: <6,202 feet (Dunlap 2001)
Cochiti Lake: <5,317 >5,370 (USCOE 2001)
Elephant Butte: < 4300 and >4,410 feet (Kirkpatrick 2001)

Safety for boaters and navigation is a key concern amongst public users, although most issues revolve around boater behavior and knowledge of protocols. However, reservoir facility managers consider "safe boating capacity" of the lake or reservoir in terms of surface area per boat. At Elephant Butte, where boating and visitor numbers are by far the greatest of any reservoir in the project area, the possible number of boats at the reservoir is limited by the number of mooring slots and tie-up points for boats. Based on average reservoir water levels (and surface areas) and maximum boat numbers, the ratio of acres per boat is well above generally accepted safe boating standards (USDOI, BLM 1999). While this is not an issue presently, setting standards at each reservoir, based on the type of boating allowed and the experience desired, would be a beneficial safeguard for maintaining safe and high quality boating opportunities.

Rapid change in elevation at reservoirs can cause muddy shoreline conditions or require additional effort by reservoir personnel to move or adjust equipment and mobile facilities. Fishing is one of the popular activities at reservoirs, and angler satisfaction is partially dependent on the quality of the fishery. Water operations can affect the reproduction and maturation of sport fishery in reservoirs. However, stocking of fish at reservoirs somewhat reduces the dependence of reservoir health on recreational fishing and angler satisfaction. If there were significant changes and long-term trends in declining fish populations angler numbers may be affected over time.

5.5 River Recreation

River-based recreation takes place at key locations where facilities have been developed and in areas where the public has access, primarily to publicly-owned land. Most facilities are beyond the zone of inundation, but some trails, picnic areas, and campsites along the river may be subject to occasional flooding. Like reservoir use, visitation to developed recreation sites is heavily influenced by a variety of factors including proximity to urban areas, availability of recreational alternatives, access to river-side facilities and put-in locations, vandalism and sense of safety for visitors, weather, and other restrictions (such as forest closures).

Few, if any, developed recreational facilities are directly within floodplains. During infrequent flood events, however, localized inundation could result in restricted access to riverside areas. This could temporarily disrupt recreational use of public trails and facilities.

Rafting, one of the most popular water-dependent activity on the river, requires certain minimal flows. **Table N-5.8** shows that under the No Action, flows would fall below 500 cfs, the preferred minimum level on the Rio Chama between El Vado and Abiquiu, on 52 percent of days during the rafting season over forty years. Through informal agreements, water operators currently time the release of water to meet desired flows of 1,000 cfs on weekends during the rafting season. Rafting would benefit from formalizing agreements to the extent that this does not conflict with meeting other priorities or contract obligations. It should be noted, that during some years, rafting operations have ceased when access to put-ins on public land were restricted due to fire hazard conditions.

Table N-5.8 Suitability for Rafting on Rio Chama between El Vado and Abiquiu

Alternative	Number <500 cfs over 40-year project life (days)[1,2]	% days
No Action	3,435	52
B-3	3,344	51
D-3	3,356	51
E-3	3,444	53
I-1	3,428	52
I-2	3,433	52
I-3	3,444	53

Source: derived from URGWOM, 40-year daily flows at gauge below El Vado, Sundin 2002a

Best

Worst

Notes:

1. Based on rafting season from April 1 through September 15 (168 days per year)
2. Estimated for gauge below El Vado, reach 6

Fishing on the Rio Chama and Rio Grande depends on suitable conditions for high quality fisheries, and for flows that are conducive to safe fishing, particularly for in-stream anglers. Angler activities have been increasing in New Mexico, due partially to population growth and increasing popularity of fishing as a recreational activity. This trend should continue under the No Action, until other pressures, such as overcrowding at favorite fishing spots or significant declines in fish populations due to a variety of threats, seriously impinge on the quality of the experience. In general, fish stocking practices by the NMDGF will continue to maintain a reasonable supply of fish for recreational purposes. **Table N-5.9** shows the relative frequency of days with flows that are suitable for fishing at selected popular fishing locations. There is little difference between alternatives on conditions along Reach 6. Reach 7, below Abiquiu has the most variation with the No Action being the least favorable. Below Cochiti, the No Action provides marginally less suitable flow conditions for anglers in Reach 10.

As reported in the Aquatic section, habitat for brown trout, the primary sport fish on the Rio Chama, and for channel catfish in the Rio Grande, would not change measurably between alternatives. This criterion is not expected to have any discernible impact on recreational fishing.

Table N-5.9 Suitability for Anglers at Selected Locations on Rio Chama and Rio Grande

Alternative	% days with suitable fishing flows (May 1 - October 1)		
	Reach 6	Reach 7	Reach 10
No Action	71	21	69
B-3	71	38	72
D-3	72	38	74
E-3	70	38	73
I-1	69	26	69
I-2	69	33	71
I-3	70	38	73

Alternative	% days with suitable fishing flows (May 1 - October 1)		
	Reach 6	Reach 7	Reach 10

Source: derived from URGWOM, 40-year daily flows at gauge below El Vado, Abiquiu and Cochiti, Hansen 2003a
Best
Worst
Notes:
1. Suitable defined as >190cfs and<830 cfs at gauge below El Vado between May 1 and October 1
2. Suitable defined as >150 cfs at gauge below Abiquiu between May 1 and October 1
3. Suitable defined as >500 cfs and <2,000 cfs at gauge below Cochiti between May 1 and October 1

5.5.1 Additional Technical Output Tables:

5.5.1.1 Reach 7

Table N-5.10: Number of Days (in 40 year period) over 50 cfs and less than 300 cfs by alternative Below Abiquiu Outfall

Alternative	# Days >50 & <300 cfs
Alt B	6,969
Alt D	7,368
Alt E	7,283
Alt I-1	6,662
Alt I-2	6,961
Alt I-3	7,291
Baserun	6,665

Table N-5.11: Number of Days (in 40 year period) over 50 cfs and less than 300 cfs by alternative during the fishing season (May 1 – October 1) Below Abiquiu Outfall

Alternative	# Days >50 & <300 cfs
Alt B	2,347
Alt D	2,312
Alt E	2,333
Alt I-1	1,578
Alt I-2	2,013
Alt I-3	2,332
Baserun	1,292

5.5.1.2 Reach 10, 12

Table N-5.12: Number of Days (in 40 year period) over 500 cfs and less than 2000 cfs by alternative Below Cochiti Outfall

Alternative	# Days >500 & <2000 cfs
Alt B	10,253
Alt D	10,379
Alt E	10,372

Alternative	# Days >500 & <2000 cfs
Alt I-1	10,183
Alt I-2	10,299
Alt I-3	10,341
Baserun	10,146

Table N-5.13: Number of Days (in 40 year period) over 500 cfs and less than 2000 cfs by alternative during the fishing season (May 1 – October 1) Below Cochiti Outfall

Alternative	# Days >500 & <2000 cfs
Alt B	4,450
Alt D	4,534
Alt E	4,520
Alt I-1	4,223
Alt I-2	4,370
Alt I-3	4,504
Baserun	4,237

5.5.1.3 Reach 6

Table N-5.14: Number of Days (in 40 year period) over 190 cfs and less than 840 cfs by alternative Below El Vado Outfall

Alternative	# Days >190 and <840 cfs
Alt B	8,622
Alt D	8,635
Alt E	8,382
Alt I-1	8,324
Alt I-2	8,310
Alt I-3	8,382
Base Run	8,396

Table N-5.15: Number of Days (in 40 year period) over 190 cfs and less than 840 cfs by alternative during the fishing season (May 1 – October 1) Below El Vado Outfall

Alternative	# Days >190 and <840 cfs
Alt B	4,371
Alt D	4,410
Alt E	4,305
Alt I-1	4,269
Alt I-2	4,271
Alt I-3	4,308
Base Run	4,346

Table N-5.16 Fishing flows analysis

During Fishing season May 1 through October 1			
Days per season	154		
Seasons	40		
total season days	6160		
suitable criteria met	>190<840	# Days >50 & <300 cfs	
	Reach 6	Reach 7	Reach 10
No Action	4,346	1,292	4,237
Alt B	4,371	2,347	4,450
Alt D	4,410	2,312	4,534
Alt E	4,305	2,333	4,520
Alt I-1	4,269	1,578	4,223
Alt I-2	4,271	2,013	4,370
Alt I-3	4,308	2,332	4,504
Score for preferred angler flows			
No Action	71%	21%	69%
Alt B	71%	38%	72%
Alt D	72%	38%	74%
Alt E	70%	38%	73%
Alt I-1	69%	26%	69%
Alt I-2	69%	33%	71%
Alt I-3	70%	38%	73%

Table N-5.17 Reservoir Visitation Levels in 2000

Heron/El Vado	244,996
Abiquiu	121,833
Cochiti	322,781
Elephant Butte	1,759,813
Caballo	247,731

Table N-5.18 Riverside Recreational Facility Impacts

Total Acres Affected

	Reach 7	Reach 8	Reach 9	RC section	Reach 10	Reach 12	Reach 13	Central Sec	Reach 14
No Action	1,384	2,364	34	**3,782**	1,911	4,821	8,494	**15,225.37**	**86,708**
ALT B	4,721	3,161	52	**7,934**	1,733	4,528	7,811	**14,071.85**	**43,274**
ALT D	4,681	2,553	34	**7,269**	3,735	8,907	14,308	**26,949.91**	**26,412**
ALT E	3,385	2,456	34	**5,875**	1,922	5,297	9,177	**16,396.14**	**23,422**
ALT I-1	4,736	3,132	52	**7,921**	4,395	9,590	14,979	**28,964.19**	**25,712**
ALT I-2	3,930	2,760	40	**6,730**	2,433	5,377	9,940	**17,750.47**	**81,371**
ALT I-3	3,300	2,519	34	**5,853**	1,957	4,930	8,896	**15,782.06**	**78,421**
	26,138	18,944	281	45,363	18,086	43,449	73,604	135,140.00	365,320

Score for total affected acres
Suitable for river-side recreation (i.e. less inundation has higher score)

	Reach 7	Reach 8	Reach 9	RC section	Reach 10	Reach 12	Reach 13	Central Sec	Reach 14
No Action	95%	88%	88%	92%	89%	89%	88%	89%	76%
ALT B	82%	83%	82%	83%	90%	90%	89%	90%	88%
ALT D	82%	87%	88%	84%	79%	80%	81%	80%	93%
ALT E	87%	87%	88%	87%	89%	88%	88%	88%	94%
ALT I-1	82%	83%	82%	83%	76%	78%	80%	79%	93%
ALT I-2	85%	85%	86%	85%	87%	88%	86%	87%	78%
ALT I-3	87%	87%	88%	87%	89%	89%	88%	88%	79%

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6.0 Land Use and Related Factors (Demographics, Regional Economics, Agriculture, Recreation, and Environmental Justice)

6.1 Existing Environment

6.1.1 Introduction

The discussion in this section includes 14 counties adjacent to the Rio Grande River and 2 additional counties linked through economic or social ties. There are two major urban centers located in the three-state study region, Albuquerque, New Mexico and El Paso, Texas. Together these two cities account for about 73 percent of the total study area population. There are several smaller municipalities located throughout the study area that make important contributions to the regional economy. Agriculture, recreation, tourism, and manufacturing are important sectors in the regional economy.

6.1.2 Population

According to the 2000 Census, there were nearly 1.7 million people in the three-state study region. Almost 1 million people were located in the New Mexico portion of the study area and most of the remaining 700,000 people were in Texas. A little over one-half of the total study area population were of Hispanic origin and slightly less than 3 percent were of American Indian origin. The percentage of the total population that is of Hispanic origin has increased significantly over the last 10 years, from 52.4% in 1990 to 57.4% in 2000. The highest percentage of Hispanic population is in the Texas portion of the study area, with about 78% of Hispanic origin in 2000. Overall, the percentage of American Indian population is relatively small, except for three counties in north central New Mexico. From 1990 to 2000 the population of the entire study area grew at an annual rate of 1.75% and it is projected to grow at a rate of 1.45% annually from 2000 to 2025.

6.1.3 Economy

The retail trade sector accounts for the largest portion of sales and business receipts in most of the study area counties. The one major exception is El Paso County, where manufacturing accounts for the largest percentage of business receipts. The large impact from retail trade is in part due to the large amount of tourism in the area. Other sectors that consistently account for large percentages of sales and receipts in the study area counties include wholesale trade, health care and social services, professional and technical services, and accommodation and food services. Wholesale trade is particularly important in the counties that include larger cities. The majority of commercial activity in the study area is in Bernalillo, Santa Fe, Sandoval, and El Paso Counties. Business activity and commercial growth over the last decade have been highest in the Albuquerque and El Paso regions.

Agriculture is an important part of the area’s economy. According to the 1997 Census of Agriculture, the total market value of agricultural products in the Colorado portion of the study area was $222 million, the New Mexico portion was $135 million, and the Texas portion was $101 million. Total farm expenses were about $168 million in Colorado, $106 million in New Mexico, and $75.5 million in Texas. A little over 9,000 people were directly employed on farms in the study region in 1999. About 33% of direct agricultural employment in the study area was in Colorado, 53% was in New Mexico, and the remaining 14% was in Texas.

Hay and wheat are the major crops grown in the Colorado portion of the study area. Hay, corn, and wheat are the major crops in the New Mexico portion of the region and cotton is predominant in the Texas portion. Some smaller crop acreages, such as Chiles in Sierra and Socorro Counties, produce important significant farm income. Approximately 40% of the land in farms in the Colorado study area counties is irrigated farmland, compared to 2% or less for the New Mexico and Texas study area counties. Cattle ranching is also an important agricultural activity in the region. In 1999 there were a little more than 200,000 head of cattle in the New Mexico part of the study area and about 100,000 head in the Colorado portion. There were about 64,000 head of cattle in the two Texas counties included in the study region.

6.1.4 Income and Employment

Median household income in the Colorado counties in 1998 ranged from $19,815 in Costilla County to $29,121 in Alamosa County. This compares to a state average of $43,400 for all of Colorado. Median household income in 1998 for the New Mexico study area counties ranged from $22,038 in Sierra County to $81,879 in Los Alamos County. Median household income in Bernalillo County (where Albuquerque is located) was $38,731 and it was $39,899 in Santa Fe County. The New Mexico state average was $31,445. The median household income in the Texas counties was $26,318 for El Paso County and $20,414 for Hudspeth County, compared to a Texas State average of $35,449. The Colorado and Texas portions of the region generally have a lower income than the New Mexico portion. Per capita personal income data show the same pattern, with the more urbanized New Mexico counties (Los Alamos, Bernalillo, and Santa Fe counties) having higher incomes than other portions of the study region. Median household income unadjusted for inflation consistently increased from 1989 to 1998 and this trend is expected to continue in the study area in the future.

Unemployment in the study region averaged 5.4% in 2001. The New Mexico portion of the region had an unemployment rate of 3.8% compared to 7.1% for the Colorado counties and 8.2% for the Texas Counties. The unemployment rate for the New Mexico counties was brought down by lower than average rates in Los Alamos County (1.0%), Santa Fe County (2.6%), and Bernalillo County (3.5%).

6.1.5 Recreation and Tourism

Recreation has a significant impact on the regional economy. Total recreation at reservoirs in the study area included more than 2.2 million visits in 2000, including visits to the following sites: Elephant Butte, 1.6 million; Caballo, 210,000; Heron, 195,000; Cochiti, 97,000; El Vado, 47,000; and Abiquiu, 37,000. Average recreation expenditures in New Mexico according to the 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation was about $46 per trip for fishing, $57 per trip for hunting, and $63 per trip for wildlife watching. Given the level of overall recreation activity in the study region, recreation related spending could exceed $100 million annually.

6.1.6 Regions of Potential Environmental Justice Concerns

Environmental Justice addresses the issue of disproportionate impacts on minority and/or low income populations. Therefore, the locations of these populations must be known in order to evaluate potential environmental justice issues. For this analysis, populations with a high percentage of people of Hispanic origin, a high percentage of Native American population, and a high percentage of low income households or high poverty rates are identified. The locations of these identified populations are used to evaluate Environmental Justice concerns.

The percentage of the population that is of Hispanic origin in New Mexico is about 42, compared to 32 percent for all of Texas, and 17 percent for Colorado. All of the study area states are well above the average for the entire U.S. of 13 percent. Therefore, the general study area could be considered to have a high percentage Hispanic population. However, the most useful comparison for evaluating the relative percentage of Hispanic population in smaller areas within the study region is to compare the percentage in individual counties and municipalities to all of New Mexico.

The highest percentage of Hispanic population areas from highest to lowest is Sunland Park (New Mexico), Fabens (Texas), the Picuris Pueblo (New Mexico), Española (New Mexico), Questa (New Mexico), Hatch (New Mexico), El Paso (Texas), and the Pueblo of Santa Clara (New Mexico). Each of these municipalities and Pueblos has populations that are 76 percent or more Hispanic.

Counties with Hispanic populations greater than for all of New Mexico (42%) include Conejos County (Colorado), Costilla County (Colorado), Saguache County (Colorado), Dona Ana County (New Mexico), Rio Arriba County (New Mexico), Santa Fe County (New Mexico), Socorro County (New Mexico), Taos County (New Mexico), Valencia County (New Mexico), El Paso County (Texas), and Hudspeth County (Texas). New Mexico Pueblos with a Hispanic population percentage greater than for all of New Mexico, in addition to the two mentioned above, include Sandia, Nambe, Pojoaque, San Ildefonso, and San Juan.

All of the areas in the study region with a high percentage of Native American population are located in New Mexico. Rio Arriba County (14%), Sandoval County (16%), and Socorro County (11%) all have Native American population percentages greater than the average for all of New Mexico (10%). Other counties with a Native American population of 4% or more of the total population include Bernalillo County (4%) and Taos County (7%). Municipalities with a Native American population percentage greater than the New Mexico average include Cuba (27%) and Magdalena (10%).

To evaluate the relative income of each county, selected municipalities, and New Mexico Pueblos in the study region, income and poverty rates for each were compared to their respective states. Those areas with income that is 70 percent or less than the state average and at least double the state poverty rate average are shown in **Table N-6.1**.

Eight counties and municipalities are identified as low income and high poverty rate as define in **Table N-6.2**. These areas include Alamosa County (Colorado), Conejos County (Colorado), Costilla County (Colorado), Saguache County (Colorado), Sunland Park (New Mexico), Cuba (New Mexico), Fabens (Texas), and Hudspeth County (Texas). Several other areas meet two of the three low income and high poverty rate criteria.

Table N-6.1 Median household income, per capita income, and poverty percentage

Region	Median household income	Per capita income	Percentage of population below poverty
UNITED STATES	$41,994	$21,587	**12.4%**
COLORADO	$47,203	**$24,049**	**9.3%**
Alamosa County	$29,447	**$15,037**	**21.3%**
Alamosa	$25,453	$15,405	15.0%
Conejos County	**$24,744**	**$12,050**	**23.0%**
Costilla County	**$19,531**	**$10,748**	**26.8%**
Rio Grande County			
Monte Vista	**$31,836**	**$15,650**	**14.5%**
	$28,393	$13,612	15.1%
Saguache County			
	$25,495	$13,121	22.6%
NEW MEXICO			
Bernalillo County	$34,133	$17,261	**18.4%**
Albuquerque	$38,788	$20,790	**13.7%**
Tijeras	$38,272	$20,884	13.5%
	$34,167	$18,836	9.5%
Dona Ana County			
Hatch	$29,808	$13,999	25.4%
Las Cruces	$21,250	$14,619	34.5%
Mesilla	$30,375	$15,704	23.3%
Sunland Park	$42,275	$25,922	9.4%
	$20,164	$6,576	39.0%
Los Alamos County			
Los Alamos	**$78,993**	**$34,646**	**2.9%**
	$71,536	$34,240	3.6%
Rio Arriba County			
Chama			
Espanola	**$29,429**	**$14,263**	**20.3%**
	$30,513	$16,670	17.9%
Sandoval County	$27,144	$14,303	21.6%
Bernalillo			
Cuba	**$44,949**	**$19,174**	**12.1%**
Jemez Springs	$30,864	$13,100	18.2%
San Ysidro	$21,538	$11,192	41.3%
Rio Rancho	$36,818	$19,522	20.8%
	$30,521	$14,787	15.1%
Santa Fe County	$47,169	$20,322	5.1%
Santa Fe			
Edgewood	**$42,207**	**$23,594**	**12.0%**
	$40,392	$25,454	12.3%
	$42,500	$18,146	10.9%

1 **Table N-6.1 (cont) Median household income, per capita income, and poverty percentage**

Region	Median household income	Per capita income	Percentage of population below poverty
NEW MEXICO **(continued)**			
Sierra County	**$24,152**	**$15,023**	**20.9%**
Elephant Butte	$31,705	$21,345	10.6%
T or C	$20,986	$14,415	23.2%
Williamsburg	$23,750	$15,549	9.6%
Socorro County	**$23,439**	**$12,826**	**31.7%**
Magdalena	$22,917	$13,064	25.1%
Socorro	$22,530	$13,250	32.3%
Taos County	**$26,762**	**$16,103**	**20.9%**
Questa	$23,448	$13,303	24.3%
Red River	$31,667	$17,883	9.7%
Taos	$25,016	$15,983	23.1%
Valencia County	**$30,099**	**$14,747**	**16.8%**
Belen	$26,754	$12,999	24.8%
Los Lunas	$36,240	$14,992	13.5%
TEXAS	**$39,927**	**$19,617**	**15.4%**
El Paso County	**$31,051**	**$13,421**	**23.8%**
El Paso	$32,124	$14,388	22.2%
Fabens	$18,486	$6,647	43.3%
Hudspeth County	**$21,045**	**$9,549**	**35.8%**
New Mexico Pueblos			
Cochiti	$35,500	$15,363	16.7%
Isleta	$29,331	$11,438	18.3%
Jemez	$28,889	$8,045	25.5%
Sandia	$29,896	$12,341	17.7%
San Felipe	$30,991	$9,266	30.8%
Santa Ana	$45,179	$9,857	5.1%
Santo Domingo	$25,664	$5,713	39.0%
Tesuque	$34,886	$16,484	18.8%
Zia	$34,583	$8,689	15.4%
Nambe	$30,452	$16,543	13.4%
Picuris	$21,136	$10,970	25.2%
Pojoaque	$34,256	$17,348	14.3%
San Ildefonso	$30,457	$14,848	12.5%
Santa Clara	$30,946	$15,336	20.0%
San Juan	$28,315	$12,083	22.7%
Taos	$23,039	$14,225	26.7%

Table N-6.2 Municipalities Defined as Low Income and High Poverty Rate

Region	Total population	White	Black or African American	American Indian	Asian	Other race	More than one race	Hispanic Or Latino
UNITED STATES	281,421,906	75.14%	**12.32%**	0.88%	3.64%	5.60%	2.43%	12.55%
COLORADO	4,301,261	**82.77%**	**3.84%**	**1.03%**	**2.21%**	**7.31%**	**2.84%**	**17.10%**
Alamosa County	14,966	**71.16%**	**0.97%**	2.34%	0.82%	20.53%	4.16%	41.41%
Alamosa	7,960	68.53%	1.41%	2.20%	0.95%	22.63%	4.28%	46.80%
Conejos County	**8,400**	**72.76%**	**0.21%**	**1.69%**	**0.15%**	**21.57%**	**3.61%**	**58.92%**
Costilla County	**3,663**	**60.91%**	**0.79%**	**2.48%**	**1.01%**	**29.65%**	**5.16%**	**67.59%**
Rio Grande County	**12,413**	**73.93%**	**0.35%**	**1.26%**	**0.23%**	**21.56%**	**2.67%**	**41.67%**
Monte Vista	4,529	63.08%	0.38%	1.61%	0.29%	31.86%	2.78%	58.20%
Saguache County	**5,917**	**71.29%**	**0.12%**	**2.06%**	**0.46%**	**23.07%**	**3.01%**	**45.26%**
NEW MEXICO	1,819,046	66.75%	1.89%	9.54%	1.06%	17.12%	3.65%	42.08%
Bernalillo County	556,678	70.75%	2.77%	4.16%	1.93%	16.17%	4.22%	41.96%
Albuquerque	448,607	71.59%	3.09%	3.89%	2.24%	14.88%	4.31%	39.92%
Tijeras	474	65.82%	0.00%	1.05%	0.21%	28.06%	4.85%	56.33%
Dona Ana County	**174,682**	**67.82%**	**1.56%**	**1.48%**	**0.76%**	**24.80%**	**3.58%**	**63.35%**
Hatch	1,673	46.03%	0.36%	0.96%	0.00%	2.63%	50.03%	79.20%
Las Cruces	74,267	69.01%	2.34%	1.74%	1.16%	4.17%	21.59%	51.73%
Mesilla	2,180	73.99%	0.23%	1.01%	0.23%	3.85%	20.69%	52.20%
Sunland Park	13,309	69.80%	0.53%	0.81%	0.07%	26.03%	2.76%	96.44%
Los Alamos County	**18,343**	**90.26%**	**0.37%**	**0.58%**	**3.78%**	**2.73%**	**2.28%**	**11.75%**
Los Alamos	11,909	89.13%	0.44%	0.56%	4.47%	3.06%	2.35%	12.21%
Rio Arriba County								
Chama	**41,190**	**56.62**	**0.35%**	**13.88%**	**0.14%**	**25.74%**	**3.28%**	**72.89%**
Espanola	1,199	67.56%	1.58%	2.67%	0.08%	25.10%	3.00%	71.23%
	9,688	67.55%	0.58%	2.86%	0.14%	25.62%	3.25%	84.38%
Sandoval County								
Bernalillo	**89,908**	**65.08%**	**1.71%**	**16.28%**	**0.99%**	**12.47%**	**3.47%**	**29.40%**
Cuba	6,611	60.17%	0.74%	3.92%	0.20%	31.34%	3.63%	74.75%
Jemez Springs	590	44.07%	0.17%	26.78%	0.68%	23.90%	4.41%	60.34%
San Ysidro	375	78.40%	0.0%	2.40%	1.87%	4.53%	12.80%	27.47%
Rio Rancho	238	30.67%	0.84%	7.56%	0.00%	53.78%	7.14%	71.85%
	51,765	78.36%	2.66%	2.37%	1.46%	11.02%	4.12%	27.68%
		73.52%	**0.64%**	**3.08%**	**0.88%**	**17.81%**	**4.07%**	**49.04%**
Santa Fe County	**129,292**	76.30%	0.66%	2.21%	1.27%	15.36%	4.20%	47.82%
Santa Fe	62,203	86.53%	0.32%	2.17%	0.21%	8.40%	2.38%	20.34%
Edgewood	1,893							

Table N-6.2 (continued) Municipalities Defined as Low Income and High Poverty Rate

Region	Total population	White	Black or African American	American Indian	Asian	Other race	More than one race	Hispanic Or Latino
NEW MEXICO **(continued)**								
Sierra County	**13,270**	**86.97%**	**0.48%**	**1.48%**	**0.17%**	**8.35%**	**2.54%**	**26.28%**
Elephant Butte	1,390	91.94%	0.07%	1.58%	0.29%	5.04%	1.08%	13.31%
T or C	7,289	85.35%	0.63%	1.77%	0.16%	9.41%	2.68%	27.36%
Williamsburg	527	91.84%	1.71%	0.76%	0.19%	1.90%	3.61%	13.09%
Socorro County	**18,078**	**62.87%**	**0.64%**	**10.92%**	**1.14%**	**20.16%**	**4.28%**	**48.73%**
Magdalena	913	62.65%	0.55%	9.97%	0.00%	5.04%	21.80%	48.30%
Socorro	8,877	66.16%	0.74%	2.77%	2.24%	23.30%	4.79%	54.50%
Taos County	**29,979**	**63.77%**	**0.35%**	**6.59%**	**0.38%**	**24.96%**	**3.95%**	**57.94%**
Questa	1,864	50.16%	0.11%	0.70%	0.05%	5.58%	43.40%	80.53%
Red River	484	92.56%	0.00%	1.03%	0.00%	2.69%	3.72%	9.30%
Taos	4,700	68.04%	0.53%	4.11%	0.62%	21.77%	4.94%	54.34%
Valencia County	**66,152**	**66.51%**	**1.27%**	**3.30%**	**0.36%**	**24.01%**	**4.55%**	**54.98%**
Belen	6,901	67.50%	1.07%	1.65%	0.17%	25.55%	4.06%	68.61%
Los Lunas	10,034	64.14%	1.16%	2.62%	0.50%	3.96%	27.63%	58.74%
TEXAS	**20,851,820**	**70.97%**	**11.53%**	**0.57%**	**2.70%**	**11.76%**	**2.47%**	**31.99%**
El Paso County	**679,622**	**73.95%**	**3.06%**	**0.82%**	**0.98%**	**18.01%**	**3.19%**	**78.23%**
El Paso	563,662	73.28%	3.12%	0.82%	1.12%	18.26%	3.40%	76.62%
Fabens	8,043	74.01%	0.57%	0.80%	0.02%	21.73%	2.86%	96.16%
Hudspeth County	**3,344**	**87.23%**	**0.33%**	**1.41%**	**0.18%**	**8.76%**	**2.09%**	**75.03%**
New Mexico Pueblos								
Cochiti	1,502	26.96%	0.53%	46.27%	0.13%	23.10%	3.00%	27.36%
Isleta	3,166	4.04%	0.06%	84.49%	0.16%	4.99%	6.25%	13.36%
Jemez	1,958	0.41%	0.00%	99.13%	0.00%	0.31%	0.15%	1.94%
Sandia	4,414	61.64%	0.45%	11.33%	0.25%	23.61%	2.72%	71.77%
San Felipe	3,185	12.53%	0.13%	77.39%	0.03%	9.04%	0.88%	17.11%
Santa Ana	487	1.44%	0.00%	97.13%	0.00%	0.82%	0.62%	2.87%
Santo Domingo	3,166	0.98%	0.00%	97.44%	0.00%	1.26%	0.32%	1.96%
Tesuque	806	28.04%	0.37%	44.04%	0.00%	25.81%	1.74%	36.23%
Zia	646	0.00%	0.00%	99.85%	0.00%	0.00%	0.15%	0.46%
Nambe	1,764	36.22%	0.00%	25.79%	0.62%	31.07%	6.29%	59.24%
Picuris	1,801	16.32%	0.28%	9.22%	0.00%	69.57%	4.61%	85.56%
Pojoaque	2,712	56.19%	0.41%	9.73%	0.22%	29.68%	3.76%	65.78%
San Ildefonso	1,524	53.22%	0.00%	34.65%	0.00%	8.66%	3.48%	45.08%
Santa Clara	6,748	62.23%	0.53%	19.68%	0.15%	14.86%	2.55%	76.22%
San Juan	10,658	64.32%	0.45%	12.47%	0.08%	19.61%	3.08%	73.48%
Taos	4,484	50.60%	0.11%	29.68%	0.29%	15.99%	3.32%	41.88%

Table N-6.2 (continued) Municipalities Defined as Low Income and High Poverty Rate

Region	Total population	White	Black or African American	American Indian	Asian	Other race	More than one race	Hispanic Or Latino
UNITED STATES	**281,421,906**	**75%**	**12%**	**1%**	**4%**	**6%**	**2%**	**13%**
COLORADO	**4,301,261**	**83%**	**4%**	**1%**	**2%**	**7%**	**3%**	**17%**
Alamosa County	**14,966**	**71%**	**1%**	**2%**	**1%**	**21%**	**4%**	**41%**
Alamosa	7,960	69%	1%	2%	1%	23%	4%	47%
Conejos County	**8,400**	**73%**	**0%**	**2%**	**0%**	**22%**	**4%**	**59%**
Costilla County	**3,663**	**61%**	**1%**	**2%**	**1%**	**30%**	**5%**	**68%**
Rio Grande County	**12,413**	**74%**	**0%**	**1%**	**0%**	**22%**	**3%**	**42%**
Monte Vista	4,529	63%	0%	2%	0%	32%	3%	58%
Saguache County	**5,917**	**71%**	**0%**	**2%**	**0%**	**23%**	**3%**	**45%**
NEW MEXICO	**1,819,046**	**67%**	**2%**	**10%**	**1%**	**17%**	**4%**	**42%**
Bernalillo County	**556,678**	**71%**	**3%**	**4%**	**2%**	**16%**	**4%**	**42%**
Albuquerque	448,607	72%	3%	4%	2%	15%	4%	40%
Tijeras	474	66%	0%	1%	0%	28%	5%	56%
Dona Ana County	**174,682**	**68%**	**2%**	**1%**	**1%**	**25%**	**4%**	**63%**
Hatch	1,673	46%	0%	1%	0%	3%	50%	79%
Las Cruces	74,267	69%	2%	2%	1%	4%	22%	52%
Mesilla	2,180	74%	0%	1%	0%	4%	21%	52%
Sunland Park	13,309	70%	1%	1%	0%	26%	3%	96%
Los Alamos County	**18,343**	**90%**	**0%**	**1%**	**4%**	**3%**	**2%**	**12%**
Los Alamos	11,909	89%	0%	1%	4%	3%	2%	12%
Rio Arriba County	**41,190**	**5662%**	**0%**	**14%**	**0%**	**26%**	**3%**	**73%**
Chama	1,199	68%	2%	3%	0%	25%	3%	71%
Espanola	9,688	68%	1%	3%	0%	26%	3%	84%
Sandoval County	**89,908**	**65%**	**2%**	**16%**	**1%**	**12%**	**3%**	**29%**
Bernalillo	6,611	60%	1%	4%	0%	31%	4%	75%

Region	Total population	White	Black or African American	American Indian	Asian	Other race	More than one race	Hispanic Or Latino
Cuba	590	44%	0%	27%	1%	24%	4%	60%
Jemez Springs	375	78%	0%	2%	2%	5%	13%	27%
San Ysidro	238	31%	1%	8%	0%	54%	7%	72%
Rio Rancho	51,765	78%	3%	2%	1%	11%	4%	28%
Santa Fe County	**129,292**	**74%**	**1%**	**3%**	**1%**	**18%**	**4%**	**49%**
Santa Fe	62,203	76%	1%	2%	1%	15%	4%	48%
Edgewood	1,893	87%	0%	2%	0%	8%	2%	20%
Sierra County	**13,270**	**87%**	**0%**	**1%**	**0%**	**8%**	**3%**	**26%**
Elephant Butte	1,390	92%	0%	2%	0%	5%	1%	13%
T or C	7,289	85%	1%	2%	0%	9%	3%	27%
Williamsburg	527	92%	2%	1%	0%	2%	4%	13%
Socorro County	**18,078**	**63%**	**1%**	**11%**	**1%**	**20%**	**4%**	**49%**
Magdalena	913	63%	1%	10%	0%	5%	22%	48%
Socorro	8,877	66%	1%	3%	2%	23%	5%	55%
Taos County	**29,979**	**64%**	**0%**	**7%**	**0%**	**25%**	**4%**	**58%**
Questa	1,864	50%	0%	1%	0%	6%	43%	81%
Red River	484	93%	0%	1%	0%	3%	4%	9%
Taos	4,700	68%	1%	4%	1%	22%	5%	54%
Valencia County	**66,152**	**67%**	**1%**	**3%**	**0%**	**24%**	**5%**	**55%**
Belen	6,901	68%	1%	2%	0%	26%	4%	69%
Los Lunas	10,034	64%	1%	3%	1%	4%	28%	59%
TEXAS	**20,851,820**	**71%**	**12%**	**1%**	**3%**	**12%**	**2%**	**32%**
El Paso County	**679,622**	**74%**	**3%**	**1%**	**1%**	**18%**	**3%**	**78%**
El Paso	563,662	73%	3%	1%	1%	18%	3%	77%
Fabens	8,043	74%	1%	1%	0%	22%	3%	96%
Hudspeth County	**3,344**	**87%**	**0%**	**1%**	**0%**	**9%**	**2%**	**75%**
New Mexico Pueblos								
Cochiti	1,502	27%	1%	46%	0%	23%	3%	27%
Isleta	3,166	4%	0%	84%	0%	5%	6%	13%
Jemez	1,958	0%	0%	99%	0%	0%	0%	2%
Sandia	4,414	62%	0%	11%	0%	24%	3%	72%

Region	Total population	White	Black or African American	American Indian	Asian	Other race	More than one race	Hispanic Or Latino
San Felipe	3,185	13%	0%	77%	0%	9%	1%	17%
Santa Ana	487	1%	0%	97%	0%	1%	1%	3%
Santo Domingo	3,166	1%	0%	97%	0%	1%	0%	2%
Tesuque	806	28%	0%	44%	0%	26%	2%	36%
Zia	646	0%	0%	100%	0%	0%	0%	0%
Nambe	1,764	36%	0%	26%	1%	31%	6%	59%
Picuris	1,801	16%	0%	9%	0%	70%	5%	86%
Pojoaque	2,712	56%	0%	10%	0%	30%	4%	66%
San Ildefonso	1,524	53%	0%	35%	0%	9%	3%	45%
Santa Clara	6,748	62%	1%	20%	0%	15%	3%	76%
San Juan	10,658	64%	0%	12%	0%	20%	3%	73%
Taos	4,484	51%	0%	30%	0%	16%	3%	42%

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APPENDIX O
CULTURAL RESOURCES

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1.0 What Are Cultural Resources?

The term cultural resource is broadly defined under three bodies of law: (1) the National Historic Preservation Act (NHPA 1966; 36 CRF 800.2.e); (2) the Archaeological Resources Protection Act (ARPA 1979; 16 USC 470); and (3) the Native American Graves Protection and Repatriation Act (NAGPRA 1990; Public Law [P.L.] 101-601).

1.1 National Historic Preservation Act

To provide some sense of the range of phenomena that is encompassed by the simple term *cultural resources*, we first turn to definitions provided under the National Historic Preservation Act (NHPA).

> Historic property means any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register. This term includes, for the purposes of these regulations, artifacts, records, and remains that are related to and located within such properties. The term eligible for inclusion in the National Register includes both properties formally determined as such by the Secretary of the Interior and all other properties that meet National Register listing criteria.

This definition subsequently has been expanded to include *traditional cultural properties*. These are defined as properties having cultural significance to one or more ethnic groups.

> "Traditional" in this context refers to those beliefs, customs, and practices of a living community of people that have been passed down through the generations, usually orally or through practice. The traditional cultural significance of a historic property, then, is significance derived from the role the property plays in a community's historically rooted beliefs, customs, and practices.

A traditional cultural property can be defined generally as one that is eligible for inclusion in the National Register because of its association with cultural practices or beliefs of a living community that (a) are rooted in that community's history and (b) are important in maintaining the continuing cultural identity of the community. Various kinds of traditional cultural properties will be discussed, illustrated, and related specifically to the National Register criteria.

Examples of properties possessing such traditional cultural significance include (a) a location associated with the traditional beliefs of a Native American group about its origins, its cultural history, or the nature of the world; (b) a rural community whose organization, buildings and structures, or patterns of land use reflect the cultural traditions valued by its long-term residents; (c) an urban neighborhood that is the traditional home of a particular cultural group and that reflects its beliefs and practices; (d) a location where Native American religious practitioners have historically gone and are known or thought to go or today to perform ceremonial activities in accordance with traditional cultural rules of practice; or (e) a location where a community has traditionally carried out economic, artistic, or other cultural practices important in maintaining its historic identity.

Finally, the NHPA has been extended to include *cultural landscapes*, defined in National Park Service Bulletin 30 as:

> a geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values.

There are four general types of cultural landscapes, none of which are mutually exclusive: historic sites, historic designed landscapes, historic vernacular landscapes, and ethnographic landscapes. Of these, the ethnographic landscape is directly relevant for this project and is defined as a:

> landscape containing a variety of natural and cultural resources that associated people define as heritage resources. Examples are contemporary settlements, religious sacred sites and massive geological structures. Small plant communities, animals, subsistence and ceremonial grounds are often components.

The NHPA provides perhaps the most all-encompassing definitions of cultural resources and is the standard that has been used during this project.

1.1.1 Archaeological Resources Protection Act

The Archaeological Resources Protection Act provides complementary definitions of cultural resources, focusing more narrowly on archaeological remains as a basis for its definition of *resources.*

> The term "archaeological resource" means any material remains of past human life or activities which are of archaeological interest, as determined under uniform regulations promulgated pursuant to this chapter. Such regulations containing such determination shall include, but not be limited to: pottery, basketry, bottles, weapons, weapon projectiles, tools, structures or portions of structures, pit houses, rock paintings, rock carvings, intaglios, graves, human skeletal materials, or any portion or piece of any of the foregoing items. . . No item shall be treated as an archaeological resource under regulations under this paragraph unless such item is at least 100 years of age.

1.1.2 Native American Graves Protection and Repatriation Act

Finally, definitions appearing in the Native American Graves Protection and Repatriation Act (NAGPRA) provide yet a third construal of what may constitute *cultural resources* (NAGPRA 1990; P.L. 101-601).

> (1) "Burial site" means any natural or prepared physical location, whether originally below, on, or above the surface of the earth, into which as a part of the death rite or ceremony of a culture, individual human remains are deposited.
>
> (2) "Cultural affiliation" means that there is a relationship of shared group identity which can be reasonably traced historically or prehistorically between a present day Indian tribe or Native organization and an identifiable earlier group.
>
> (3) "Cultural items" means human remains and items of "cultural patrimony" which shall mean an object having ongoing historical, traditional, or cultural importance central to the Native American group or culture itself, rather than property owned by an individual Native American, and which, therefore, cannot be alienated, appropriated, or conveyed by any individual regardless of whether or not the individual is a member of the Indian tribe or Native Hawaiian organization and such object shall have been considered inalienable by such Native American group at the time the object was separated from such group.

From these three bodies of legislation, it is possible to find statutory bases for defining *cultural resources* as:

- Individual buildings or groups of buildings, whether prehistoric or historic in age.
- Archaeological sites, both prehistoric and historic, as well as artifacts in those sites.

- Graves, even if not situated in nominal archaeological sites.
- Traditional cultural properties that play a role in a community's historically rooted beliefs, customs, and practices. This may include properties important to Native American or other ethnic groups.
- Cultural landscapes consist of geographic areas of varying size including ethnographic landscapes that associated people define as heritage resources (e.g., contemporary settlements, religious sacred sites, massive geological structures or religious or cosmological importance, small plant communities where plants used in rituals are obtained, small animal communities where animals used in rituals are obtained, and specific areas used to conduct ceremonies).

All these classes of *cultural resources* are considered as part of the Review and Environmental Impact Statement (EIS) analysis. Among the cultural resources known in the planning area are archaeological sites, historic and prehistoric buildings, potential cultural landscapes, and traditional cultural properties (TCPs). Each of these is discussed in a preliminary fashion below. It should be emphasized that these are not mutually exclusive categories; it is quite possible to have historic buildings in archaeological sites that constitute traditional cultural properties, all of which are situated in cultural landscapes.

1.1.3 Archaeological Sites

More than 6,838 known prehistoric and historic archaeological sites are situated in the planning area. Of the known sites, approximately 40 (0.6 percent) would be directly impacted as a result of proposed changes in water operations.

Based on variations in surveyed acres and estimated site densities, approximately 153,000 archaeological sites are projected to be located within the planning area. Of the projected number of sites, between 383 and 465 sites (0.3 percent of the total) would be adversely affected by proposed changes in water operations.

1.1.3.1 Historic Buildings

Historic archaeological sites are present among the known sites in the planning area. However, current evidence indicates that none of these sites would be affected by proposed changes in water operations.

1.1.3.2 Cultural Landscapes

It is difficult to ascertain whether cultural landscapes—whether Native American, Spanish, or Anglo—will emerge as important in the planning area. However, recently there have been changes in zoning regulations in Rio Arriba County designed to protect agricultural lands. This suggests that agricultural lands may constitute Spanish cultural landscapes in the statutory sense of the term. Similarly, it is likely that certain parts of the planning area may be deemed cultural landscapes by Native American communities. Spanish cultural landscapes tend to be concentrated in the Rio Chama Basin (Reaches 5, 6, and 7), while Native American cultural landscapes are concentrated along the mainstem of the Rio Grande in Reaches 8, 9, 10, 11, and 12.

1.1.3.3 Traditional Cultural Properties

At a bare minimum, there are two general classes of TCPs found within the planning area. The first of these are New Mexico’s acequias. All of the state’s acequias have been determined by the New Mexico Office of Cultural Affairs, Historic Preservation Division, to be eligible for inclusion on the National

Register of Historic Places (NRHP) as TCPs. Acequias occur near and within traditional Spanish towns and villages along the Rio Chama.

The second class of TCPs found within the planning area is sites sacred to New Mexico's Native American communities. These are *de jure* eligible for inclusion on the NRHP as TCPs. The spatial distribution of these sites relative to the projected impact zones associated with each of the EIS alternatives is as yet unknown.

Still other TCPs may also emerge. For example, it is quite likely that reaches of the Rio Grande containing certain kinds of plants may be found to be TCPs if these plants are used by Native Americans in religious and other ceremonies.

What follows is a broad overview of the development of Native American, Spanish, and Anglo-American communities across the large and complex landscape encompassed by the planning area. This discussion provides a historical context within which specific cultural resources—archaeological sites, historic buildings, cultural landscapes, and traditional cultural properties—may be viewed. Without this context, is virtually impossible to accurately interpret cultural resources in the project area or, equally important, begin to evaluate the potential effects of proposed changes in water operations on these cultural resources.

1.2 Prehistory

The planning area contains evidence of prehistoric occupations designated by archaeologists as *Anasazi* and *Mogollon*. This distinction is predicated on differences in ceramics, architecture, and myriad other archaeological evidence that has been amassed over the past century. The northern reaches of the project area contain remains typical of Anasazi occupations, while Mogollon occupations are typical of the southern reaches. Areas along the boundary between these two geographically defined types of occupations often contain evidence of both Anasazi and Mogollon occupations.

Archaeologists working in different parts of the Anasazi and Mogollon culture areas have defined regional phase sequences based on subtle differences in the characteristics of artifacts associated with sites, as well as slight differences in the ages of remains in certain regions. Regional phase sequences, presented in **Table O-1.1,** include these more focused phase sequences for the San Juan, Middle Rio Grande, Gallina, Rio Abajo, and Jornada portions of the project area. These regional phase sequences are contrasted with the more generalized Pecos sequence that was used during the early years of archaeological investigations across the region.

There are two terms appearing in the following discussions that require explanation. The term *site* refers specifically to a bounded geographic location that contains evidence of past human occupations. The use of the term *occupations* in this definition recognizes that many sites (i.e., locations) may contain evidence of occupations spanning substantial periods of time. Each of these time-sequent occupations are termed *components*. Consequently, it is almost always the case that the number of *components* is greater than the number of *sites*. Accordingly, there will be variations between the numbers of sites and the numbers of components that appear in the tables that follow.

Table O-1.1. Regional Phase Sequences in the Planning Area

Age	San Juan Basin	Middle Rio Grande	Gallina	Rio Abajo	Jornada	Pecos Classification
1900						
1800						
1700	Cabezon		Cabezon			
1600						
1500	Gobernador	Historic	Gobernador			
1400	Dinetah	Pueblo IV	Dinetah	Historic Piro	Historic	Historic
1300						
1200	Pueblo III		Largo-		El Paso	Pueblo IV
1100		Coalition-		Late		Pueblo IV
1000					Doña Ana	Pueblo II
900	Pueblo II		Arboles	Early	Mesilla	
800						
700			Piedra	Tajo		Pueblo I
600	Pueblo I	Pueblo II				
500						
400		Pueblo I	Rosa			Basketmaker III
300			Sambrito			
200	Basketmaker III			San Marcial	Hueco	
100						
0	Basketmaker II					
-100			Los Piños			Basketmaker II
-200		Basketmaker III				
-300						
-400						
-500	En Medio					Basketmaker I
-600						
-700						
-800						
-900						
-1000	Armijo	Rio Rancho		Archaic	Fresnal	Archaic

Mention must be made of the overall character of archaeological sites in the northernmost portion of the project areas, which are situated in southern Colorado and includes Reaches 1 and 2. There are no proposed changes in water operations in this part of the project area and so this summary is quite general.

Colorado archaeological records are recorded in a system that is quite different from New Mexico Cultural Resources Information System (NMCRIS). Since it is impossible to completely correlate the Colorado system with that used in New Mexico, simple queries regarding the character of prehistoric and historic archaeological sites are presented below. Records obtained from the State Historic Preservation Office in Denver, Colorado, indicate that 813 sites are situated adjacent to Reaches 1 and 2. Reach 1 encompasses 643,415,000 acres and contains 217 sites. Reach 2, which encompasses the margins of the Rio Grande mainstem, contains 1,151,590,000 acres and 591 sites. At first glance, this might suggest that fully 73 percent of the total known sites for the two reaches combined are situated in Reach 2. However, once the size of the two reaches is standardized, it is evident that there are minimal differences in the overall numbers of archaeological sites between these two reaches.

The majority of sites in Reach 1 and Reach 2 are of unknown affiliation and time period (**Table O-1.2**). Of those that can be assigned to specific time periods, most date to the middle-late Archaic Period, with progressively smaller numbers of sites dating to later prehistoric times. Historic sites (e.g., Ute, Hispanic, Euro-Anglo) are also rare, perhaps indicating that this part of the project area was not settled until relatively recently.

Table O-1.2. Summary of Site Cultural Affiliations in Reaches 1-2 (Colorado)

Cultural Affiliation	Reach 1	Reach 2	Total
	Site Frequency	Site Frequency	
PaleoIndian	2	1	3
General Archaic	3	4	7
Early Archaic	0	2	2
Mid-Late Archaic	0	13	13
Late Archaic	2	21	23
Archaic/Puebloan	0	1	1
PaleoIndian-Archaic	0	1	1
BM II	0	1	1
II - PIII	0	1	1
Pueblo III	2	0	2
PIV-Late Prehistoric	6	4	10
Anasazi	5	2	7
Unknown Cultural Affiliation	76	166	242
Unknown Aboriginal	30	29	59
Historic Ute	0	2	2
Hispanic	0	3	3
Euro-Anglo	1	2	3
No data	90	326	416
TOTAL	217	579	796

Table O-1.3. Summary of Site Types and Sizes in Reaches 1-2 (Colorado)

Code	Site Types	Reach 1		Reach 2	
		Number	Size (m2)	Number	Size (m2)
1	Open Lithic	19	5923	81	7923
2	Open Architectural	5	9890	17	54250
3	Open Camp	14	2310	20	6348
4	Rock Art	2	3050	0	N/A
5	Historic Period	1	400	7	1434
6	Sheltered Camp	0	N/A	0	N/A
7	Stone Quarry	0	N/A	0	N/A
8	Historic Trash Scatter	2	12810	1	N/A
9	Historic Foundations	0	N/A	0	N/A
10	Isolated Find	3	178	50	98
11	Isolated Feature	0	N/A	0	N/A
12	Herding/Sheep Camp	2	5375	3	11367
13	Mining Operation	13	8424	0	N/A
14	Lumbering Operation	0	N/A	1	N/A
15	Railroad Related	0	N/A	1	N/A
16	Sheltered Architectural	0	N/A	0	N/A
17	Historic Cabin	4	4705	0	N/A
18	Tree Carvings	0	N/A	0	N/A
19	Quarry	1	135	11	6242
20	Unspecified	156	N/A	399	N/A
	OVERALL TOTAL	**222**	**5,407**	**591**	**10,285**

Table O-1.4. Frequency of Archaeological Components in Reaches 3-16 of the Northern Project Area.

Reach	PaleoIndian	Archaic	Anasazi	Anasazi/ Mogollon	Mogollon	Puebloan	Ute	Apache	Navajo	Hispanic	Anglo	Unknown	Totals
3	1	107	111	0	0	11	0	5	1	29	21	219	505
4	0	2	24	0	0	8	0	0	0	12	5	11	62
5	0	9	10	0	0	0	0	1	0	17	14	82	133
6	3	129	324	0	0	10	21	3	48	34	31	327	930
7	4	112	283	0	0	20	1	4	5	52	16	261	758
8	0	6	82	0	0	10	0	0	0	26	15	31	170
9	1	94	1068	0	0	67	0	0	0	19	22	665	1936
10	2	36	220	0	0	54	0	0	0	27	18	308	665
11	1	15	37	0	0	28	0	0	0	3	4	50	138
12	1	27	267	0	0	33	0	1	1	81	69	206	686
13	0	5	70	12	0	12	0	0	0	77	30	23	229
14	2	40	68	117	39	19	0	2	0	60	66	125	538
15	0	5	1	0	63	0	0	0	0	2	41	64	176
16	2	64	1	0	398	1	0	2	0	12	118	289	887
Totals	**17**	**651**	**2566**	**129**	**500**	**273**	**22**	**18**	**55**	**451**	**470**	**2661**	**7813**

1.2.1 Early Prehistory of the Planning Area

Despite the geographic extent of the planning area, the early prehistory of the region exhibits many commonalities through the PaleoIndian (*Circa* [*ca.*] 11,000 B.C. to *ca.* 7,000 B.C.) and Archaic (*ca.* 7,000 B.C. to *ca.* A.D. 300) Periods. It is only during the Formative Period (*ca.* A.D. 500 to A.D. 1492) that regional differences in the character of prehistoric occupations emerge.

Accordingly, the discussion of PaleoIndian and Archaic occupations focuses on general similarities across the project area as a whole. In contrast, the discussion of Formative Period occupations divides the project area into various subareas (e.g., Northern Rio Grande, Middle Rio Grande, and West Texas) whose archaeological characteristics are internally similar, but that differ from each other in subtle ways.

Region-specific phase sequences are presented in **Table O-1.1**. In general, the prehistory of the northern planning area is divided into five major periods. The earliest evidence of human occupations in the region is termed PaleoIndian. This is followed by the Archaic Period during which the beginnings of agriculture emerge in the archaeological record. Subsequent developments are designated as the Formative, or Developmental, Period when agriculture and large towns began to appear across the Colorado Plateau. This, in turn, is followed by the Historic Period which includes developments by both American Indians, as well as later Euro-American settlers.

1.2.2 PaleoIndian Period (*ca.* 10000 B.C. to 5500 B.C.)

The PaleoIndian Period was characterized by relatively small bands of hunters relying on large, now-extinct, Pleistocene megafauna (i.e., mammoth and bison), many of which were migratory. As a result, PaleoIndian sites are ephemeral, reflecting periodic movement of camps to areas where animals might be found. There is also evidence of reliance on plant resources. Such high mobility is accompanied by relatively low archaeological visibility and the overall number of PaleoIndian sites known in the project area as a whole is quite low (Biella and Chapman 1977:113; Kirkpatrick et al. 2000:85; Scheick et al. 1991:107)

PaleoIndian sites have been found in a variety of settings. The first is along the margins of playas small ephemeral lakes that hold water for short periods during the rainy season (Judge and Dawson 1972). The second setting where PaleoIndian sites are found is along ridge lines paralleling large drainages where water might be available (Vivian 1990:81), as well as immediately adjacent to the mainstem of the Rio Grande (Marshall and Walt 1984:17; Scheick et al. 1991:107). Small PaleoIndian sites consisting of chipped stone artifacts; occasional hearths have been found in uplands settings adjacent to the Rio Grande, notably in the Cochiti Dam region (Biella and Chapman 1977:113).

In the northern reaches of the project area, PaleoIndian sites are known from the Puerco Basin, the Española Basin, the Chuska Valley along the Arizona-New Mexico border, and the Chaco Plateau (Vivian 1990:81). Most consist of isolated projectile points, again consistent with a highly mobile way of life (Scheick et al. 1991:107-108). PaleoIndian occupations have tentatively been identified from cave sites situated in the Sandia Mountains near Albuquerque (Schutt and Chapman 1992:24) and from mesa settings overlooking the Rio Grande near Rio Rancho, as well as from floodplain settings near Socorro (Weber 1963).

To the south, between the Rio Puerco to downstream below Elephant Butte Reservoir, artifacts consistent with Clovis and later Folsom occupations also have been found (Beckes 1977; Broilo 1973; Camilli et al.

1988; Cordell 1979; Eidenbach 1983; Elyea 1987; Everett and Davis 1974; Harkey 1981, Kauffman 1984; Krone 1976; MacNeish 1991; Quimby and Brook 1967; Russel 1968; Weber and Agogino 1968). Clovis remains are quite rare, probably because sites from this period are generally scarce in near-riverine setting (Marshall and Walt 1984:21).

Specialized tools in the form of end-scrapers, denticulates, notched flakes, and bifacial and unifacial knives characterize most PaleoIndian assemblages (Judge 1973; Chapman 1977). In addition, sites from this period exhibit large bifacial projectile points. These points were attached to wooden shafts to form atlatls, or throwing sticks. Variations in the ways these points were manufactured, specifically reliance on fluting and lateral thinning, have allowed archaeologists to separate the PaleoIndian Period into three time-sequent complexes. The earliest complex is typified by non-fluted Clovis points. Later, fluted points signal the appearance of the Folsom complex. Finally, points typified by extreme lateral thinning are indicative of the Plano complex.

Detailed analyses of archaeological site records from the NMCRIS indicate that there are 17 sites with PaleoIndian occupations in the planning area (**Table 0-1.5**). PaleoIndian components constitute approximately 0.2 percent of the total number identifiable components in the project area. PaleoIndian sites are found in approximately 60 percent of project area reaches, but are more common in Reaches 6 and 7.

1.2.3 Archaic Period (*ca.* 5500 B.C. to A.D. 400)

The Archaic Period consists of more diversified adaptations that began approximately 8,000 years ago and persisted until about 2,000 years ago. The Archaic Period is signaled by the extinction of earlier Pleistocene fauna due to the combined effects of drought and possible over-hunting by PaleoIndian peoples. The decline in big game hunting as a major subsistence focus was replaced by a more diversified set of exploitative technologies.

Although hunting remained important throughout the Archaic Period, there was greater emphasis on smaller game (e.g., deer). Projectile points decrease in size consistent with the hunting of smaller animals. This was accompanied by greater reliance on gathering of wild plant resources. Consonant with this subsistence shift is the appearance of new classes of artifacts, notably ground stone implements used to process plant foods for consumption.

Table O-1.5. Summary of PaleoIndian and Archaic Phase Occupations in the Planning Area

Reach	PaleoIndian	Archaic	TOTAL
3	1	107	108
4	0	2	2
5	0	9	9
6	3	129	132
7	4	112	116
8	0	6	6
9	1	94	95
10	2	36	38
11	1	15	16
12	1	27	28
13	0	5	5
14	2	40	42

Reach	PaleoIndian	Archaic	TOTAL
15	0	5	5
16	2	64	66
17	0	0	0
TOTAL	**17**	**651**	**668**

The appearance of broader spectrum hunting and gathering subsistence practices was accompanied by increases in the number and size of resource zones and in the variety of resources that were utilized. Consistent with this subsistence change, settlement patterns also changed noticeably so that Archaic sites found in a broader variety of elevational and topographic settings (Dick 1965; Human Systems Research 1972; Laumbach 1980a; Martin et al. 1949; Whalen 1971).

As in the PaleoIndian Period, Archaic hunting-and-gathering groups seem to have remained small in size, probably consisting of no more than a few co-residential, extended families. Archaic sites are more visible than PaleoIndian sites, but also remain relatively ephemeral. This is again consistent with high mobility when groups continually move to take advantage of geographic and seasonal variations in the availability of plant and animal resources.

Variability in projectile point production technologies (e.g., hard versus soft hammer percussion, basal thinning, corner-notching) suggests that regional differentiation was developing (Taylor 1964; Winters 1969). Social groups were probably still organized at the family and band level, with a concurrent high degree of residential mobility inferred for these groups.

In the northern portion of the planning area, Archaic sites are best known from the Navajo Reservoir region southward to Gallegos Mesa, the Española Basin, the Rio Santa Cruz Basin, the Galisteo Basin, the Chuska Valley, the Chaco region, and Arroyo Cuervo (Scheick et al. 1991:115-119). Beginning with relatively few early Archaic Jay phase (*ca.* 5500-4800 B.C.) sites, there is a progressive increase in the number of later Bajada (ca, 4800-3200 B.C.), San Jose (*ca.* 3000-1800 B.C.), Armijo (*ca.* 1800-800 B.C.) and En Medio (800 B.C. - A.D. 400) phase sites in the northern portion of the project area (Irwin-Williams 1979). Sites tend to be larger by the San Jose phase and are accompanied by the first evidence of structures, probably constructed of poles and brush. The number and size of sites increases steadily in succeeding phases, all of which is consistent with the aggregation of larger groups of people, generalized population growth, and repeated occupations of larger base camps. Some of the earliest evidence for domesticated crops, specifically maize, appears among Armijo phase sites in the northern part of the project area in the San Juan Basin.

Sites tend to alternate between semi-permanent (winter) base camps that were repeatedly occupied from year to year and more ephemeral (summer) sites related to specific seasonal hunting or gathering activities. Sites are common along canyon heads and cliff tops, as well as in floodplain environments and escarpments overlooking the Rio Grande (Scheick et al. 1991:109-110; Snead 1995). Based on ethnographic analogies, the size of territories exploited by Archaic groups was inversely proportional to environmental diversity: where diversity was higher, territories probably were smaller and the converse.

In the southern portion of the planning area, the Archaic Period is divided into the Gardner Springs (6000-4000 B.C.), Keystone (4000-2500 B.C.), Fresnal (2500-900 B.C.), and Hueco (900 B.C.-A.D. 250) phases. These temporal distinctions are based on changes in tool technology, primarily projectile point types. Small numbers of Archaic sites have been found in Socorro, Sierra, and Doña Ana counties (Kirkpatrick et al. 2000:97).

Archaic sites are generally situated along the margins of the Rio Grande on the east and west mesas adjacent to Las Cruces and parallel to the Rio Grande (Ackerly 1999; Camilli et al. 1988; Marshall and Walt 1984; Lekson 1985; Ravesloot 1988; Seaman et al. 1988), as well as in the San Andres Mountains and White Sands Missile Range to the east (Eidenbach 1983). Archaic sites are generally absent from the floodplain of the Rio Grande, due probably to avulsive channel migration events that would have periodically scoured parts of the floodplain, thereby removing evidence of occupations (Kirkpatrick et al. 2000:66-67; Marshall and Walt 1984:21). Sites do, however, seem more common in dune fields adjacent to the mainstem of the Rio Grande, as well as along escarpments paralleling the river (Marshall and Walt 1984:21). General trends in the number of Archaic sites across the project area are interpreted as reflecting gradual, sustained population growth throughout the Archaic Period (MacNeish and Beckett 1987; Minnis 1980).

Further downstream, cave sites near Bishop's Cap, southeast of Las Cruces, have yielded preserved maize that dates to around 3000 B.C. (Upham et al. 1987). These are among the earliest dates known for domesticated crops in the American Southwest and presage the much greater reliance on domesticated crops that characterizes the later prehistory of the project area.

The appearance of maize in the Archaic Period archaeological record is accompanied by the almost simultaneous appearance of more permanent structures and storage facilities presumably for storing surplus maize. Stylistic variations among projectile points increased drastically during the Archaic. Such wide variations can possibly be explained by regional differentiation among various Archaic groups with attendant decreases in interaction and the exchange of information. This may have been further exacerbated by progressively greater differentiation in the economic pursuits of these groups.

Detailed analyses of archaeological site records from NMCRIS indicate that there are 651 sites with Archaic occupations in the planning area (**Table 0-1.5**). Archaic components constitute approximately 8.3 percent of the total number identifiable components in the project area. Archaic sites are more prevalent in Reaches 3, 6, 7 and 9, but are found in all of the project reaches.

1.2.4 Formative Period (*ca.* A.D. 500 to A.D. 1492) in the Planning Area

During the Formative Period, the prehistory of the planning area begins to become geographically differentiated. This is almost certainly due to appearance of the Chaco phenomenon, a sequence of development centered in the Chaco Canyon region that had profound effects in the northern part of the project area, but whose effects were attenuated in the southern reaches of the project area. Accordingly, what follows is a discussion of the prehistory of the northern and southern parts of the project area. Based on the spatial distributions of archaeological sites assigned to specific cultures, the northern area referred to in this appendix includes Reaches 1 through 12. In the Review and EIS, these reaches are found in the Northern Section (Reaches 1 through 4), the Rio Chama Section (Reaches 5 through 9), and the upper portion of the Central Section (Reaches 10 through 12). The southern area referred to in this appendix includes Reaches 13 through 17. In the Review and EIS, these reaches are found in the Central Section (Reach 13), the San Acacia Section (Reach14), and the lower portion of the Southern Section (Reaches 15 through 17).

1.2.5 The Northern Area (Reaches 1 through 12)

The northern portion of the project area contains remains typically referred to as *Anasazi*. Archaeological sites affiliated with Anasazi occupations are common in the Rio Chama Bbasin (Schaafsma 1976; Whitten and Powers 1980), along the mainstem of the Rio Grande into the Cochiti Reservoir area (Biella and Chapman 1977), and southward into the Albuquerque region (Schutt and Chapman 1992).

The sequence of prehistoric development in the northern planning area progresses through the Basketmaker and Puebloan occupations dating. Within these two broad cultural periods are numerous time-sequent phases, each of which is discussed below. The overall number of site components (i.e., occupations) dating to specific phases is summarized by reach in **Table O-1.6**.

1.2.5.1 Basketmaker III (ca. A.D. 500-700)

Basketmaker (BM) III occupations in the northern portion of the planning are characterized by widespread use of domesticated crops accompanied by the appearance of pithouses, the advent of ceramic manufacturing, and the introduction of bow-and-arrow technology. Crops recovered from sites dating to this period include maize, squash, and beans. The adoption of agriculture was probably facilitated by a return to increases in effective moisture over much of the Colorado Plateau during this period. Yet, indirect evidence of droughts during this period suggests that this was not a stable climatic regime. As a consequence, BM III groups continued to rely on wild plant and animal resources, with agricultural products largely used to supplement wild resources.

Population growth continued during BM III at relatively high rates, with the cumulative effect that BM III groups became more densely packed into the landscape. The presence of neighboring groups who also depended on the same resources would have constrained the ability of any one group to complete seasonal movements to obtain wild plant and animal resources. Such constraints on movement, in conjunction with improved climatic conditions, contributed to the more widespread adoption of cultivated crops during this period. Similarly, by late BM III times, a major population shift from the La Plata region into the central portion of the San Juan Basin had occurred, perhaps in response to improved agricultural conditions.

Table O-1.6. Summary of Anasazi Phase Components in the Northern Project Area

Reach	BM III	P I	P II	P III	P IV	TOTAL
3	45	26	39	57	51	218
4	7	7	7	15	22	58
5	0	0	0	8	2	10
6	63	101	123	207	62	556
7	24	19	22	136	248	449
8	23	25	29	61	52	190
9	224	226	239	710	795	2194
10	55	76	71	125	135	462
11	12	14	15	19	25	85
12	87	83	69	131	159	529
13	11	13	26	50	35	135
14	20	25	27	49	39	160
15	0	1	0	0	0	1
16	0	0	0	0	1	1
17	0	0	0	0	0	0
TOTAL	571	616	667	1568	1626	5048

Note: BM = Basketmaker; P = Pueblo

BM III sites are known from the Navajo Reservoir region, Animas-La Plata Basin, Red Rock Valley, Arroyo Hondo, Middle Chuska Valley, the Chaco Canyon region, near the confluence of the Rio Grande and Santa Fe River, and southward into the Puerco Valley and along the floodplain of the Rio Grande south of the Rio Puerco (Marshall and Walt 1984:35; Scheick et al. 1991:120; Vivian 1990). Relative to earlier periods, BM III sites are far more visible due to longer occupations and, compared to earlier times, BM III sites are disproportionately oriented toward areas containing arable land. Agriculture during this period relied exclusively on direct rainfall; technologies such as irrigation to supplement water supplies have not been found.

There is evidence that BM III was not the same across all parts of the San Juan Basin. Early BM III groups in the southwestern and western portions of the basin continued to practice hunting-and-gathering to a much greater extent than agriculture. In contrast, there is evidence of greater agriculture in the Navajo Reservoir, accompanied by substantially higher populations.

This dichotomy between "more agricultural" and "less agricultural" groups may have formed the basis for simple exchange systems that, in later times, became far more elaborated. Such early exchange systems would have focused on trade of agricultural products for wild resources. By late BM III times, however, reliance on agriculture appears to be general across the entire project area.

1.2.5.2 Pueblo I (ca. A.D. 700-900)

The Pueblo I (P I) Period on the Colorado Plateau is typified by an increase in the number of sites, an increase in average site size, the appearance of above-ground jacal and stone architecture alongside semi-subterranean pithouse structures, and larger storage facilities. Above-ground structures typically exhibit linear or oval configurations and contain about 8 rooms per site. Proto-kivas first make their appearance at some P I sites in the project area. With the exception of the Chaco region, these trends are not thought to reflect population growth, but rather consolidation of previously distinct residential groups into larger villages.

In the San Juan Basin, the overall number of Pueblo I sites is relatively low. This is attributed, in part, to deteriorating environmental conditions on the Colorado Plateau—specifically, reduced rainfall and an increase in the overall variability of rainfall. Rainfall estimates appear relatively high between A.D. 700-750, but began a steady decline through the early A.D. 800s. Between A.D. 830 and 900, drought conditions are thought to have prevailed over much of the project area.

The highest concentrations of P I sites are situated in the Mesa Verde region, in the Middle Chuska Valley, Chaco Canyon, Lower Chuska Valley, the Navajo Reservoir region, the Taos Basin, the Santa Fe Basin, and south into the Albuquerque area (Wendorf 1953:94-95). The easternmost manifestation of P I, termed the Rosa-Loma Alta phase of the Gallinas region, differs slightly from sites situated further west. Here, settlements tend to be distributed not only along drainages, but also on outwash fans to maximize agricultural production. Over much of the northern San Juan basin, sites tend to be situated on mesas, broad ridges, or floodplain terraces overlooking drainages. To the south, sites of this period are less common in the Rio Puerco and southward toward Elephant Butter Reservoir (Marshall and Walt 1984:47).

As in BM III times, there is evidence for regional differentiation in subsistence patterns. In the southwestern portion of the San Juan Basin, sites assigned to the White Mound-Kiatuthlana phases contain food remains indicating reliance on a mix of horticulture, hunting, and gathering. In the northern San Juan Basin, Piedra phase sites tend to contain relatively larger amounts of cultigens. In the center of the San Juan basin, in Chaco Canyon, P I sites contain a similar mix of domesticated and wild resources, suggesting that drought conditions during this period caused subsistence strategies to remain diversified. To the east, reliance on domesticates appears to have been greater than in other parts of the basin.

1.2.5.3 Pueblo II (ca. A.D. 900-1050)

The Pueblo II Period is characterized by an increase in the number of sites, an increase in average site size, a shift toward above-ground, coursed masonry architecture, the appearance of larger numbers and larger sizes of storage facilities, and the appearance of formal kivas, particularly at sites in the Chaco Basin. Habitation sites typically contain between 6 and 9 rooms per site, most arranged in a linear fashion oriented north-south. Larger sites containing more numerous rooms are often laid out in a quadrilateral pattern with central plazas.

During P II times, the Chaco phenomenon truly flourishes, characterized by the establishment of very large towns, the appearance of multistoried room blocks, increasingly complex architectural elaboration of kivas, the advent of field systems in an effort to boost agricultural production, and the development of road systems to facilitate trade and exchange.

These changes signal a return to accelerating population growth in response to dramatically improved climatic conditions, specifically a return to higher rainfall levels, accompanied by episodic droughts whose intensity varied from place to place. In areas less affected by droughts, settlements pushed into areas that would have been marginal in P I times. Differential spatial distributions of critical resources probably became more pronounced in P II times over much of the San Juan Basin.

In short, much of the P II Period is typified by imbalances between people and resources, both temporally and geographically. These imbalances necessitated the introduction of various buffering mechanisms in an effort to offset them, including improved storage facilities, expansion of regional exchange networks, and more frequent abandonment and reestablishment of large villages in areas better suited for agriculture. One consequence is that P II sites often were occupied for relatively short periods of time.

Subsistence practices indicate greater reliance on cultivated plants, although evidence of use of wild resources persists at most P II sites. Maize, beans, and squash are quite common at both large and small sites. The first water control structures in the San Juan Basin date to this period. These structures were designed to augment rainfall, thereby increasing overall productivity of given plots of land. Many of these water control devices seem to provide water to outwash fans, areas that are often marginal for direct rainfall agriculture.

P I sites are situated in the Mesa Verde region, in the Middle Chuska Valley, in the Española and Santa Fe Basins, Chaco Canyon, Lower Chuska Valley, the Navajo Reservoir region, and south from the Rio Puerco to near Truth-or-Consequences, New Mexico (Scheick et al. 1991:122-123, 126; Marshall and Walt 1984:47). Sites are found in riverine areas along the Rio Chama, Rio Grande, Rio Santa Cruz, Tesuque Valley, and the Santa Fe River Basin, as well as upland areas along the escarpment of these drainages. Sites of this period are also found in riparian environments in southerly tributaries such as the Rio Puerco (Marshall and Walt 1984:75).

Earlier dissimilarities between sites in the southern San Juan Basin and those in the northern basin largely disappear during P II times. The emergence of region-wide homogeneity in ceramics, architecture, subsistence practices, and settlement patterns supports the inference that region-wide trade and exchange systems emerge and in full force during P II times.

One notable exception to this homogeneity is found in the Chaco Canyon region, where Great Kivas and Great Houses are common. Kivas of this type are generally absent in the northern part of the San Juan Basin and are quite rare in the southern part. Similarly, Great Houses are also restricted largely to the Chaco Canyon region. Settlements in the Chaco heartland typified by numerous small habitation sites distributed around fewer, but very much larger and more complex, towns (central places) containing kivas, reservoirs, dams, and roads. Nonlocal materials were imported from other parts of the Southwest.

These facts, combined with the pan-regional distribution of ceramics that are virtually identical, suggests that Chaco Canyon may have been the primary focal point for trade and exchange networks whose limits extended into northeastern Arizona, southern Colorado, and west-central New Mexico (Scheick et al. 1991:127). Analyses of ceramics and chipped stone indicate that source areas for such critical resources gradually shifted over time from the southeastern part of the basin (Zuni) toward the western (Chuska) region and, finally, to the northern portion of the San Juan Basin. It is likely that these regions approximate the outer limits of this exchange and trading network. There is some evidence suggesting that turkeys and corn were among the crucial subsistence resources imported into the Chaco region. Reliance on imported foodstuffs underscores the tenuous agricultural conditions that seem to have prevailed across the central San Juan Basin during P II times.

1.2.5.4 Pueblo III (ca. A.D. 1050-1300)

The P III Period is typified by the aggregation of populations into progressively larger centers, accompanied by the gradual collapse of the Chaco phenomenon that defines early and middle P II times. Populations may have begun to move northward into the northern San Juan Basin near Aztec and southward out of the Mesa Verde region during this period.

Concurrent with Chaco's gradual decline in importance is a realignment of social interactions northward toward Mesa Verde. For example, sites along the Chuska Mountains evidence a period of increased building events, accompanied by the replacement of Chacoan ceramics with those more typical of Mesa Verde. The appearance of bi- and tri-wall buildings—nominally characteristic of the Mesa Verde region—at sites in the San Juan Basin suggests the gradual outward expansion of Mesa Verde peoples into areas formerly containing Chaco components. Over much of this period, sites contain between 13 and 30 rooms, with larger sites exhibiting as many as 200 rooms.

These changes are attributed to the onset of a period of dramatically decreased rainfall after around A.D. 1220, accompanied by increased spatial variability in rainfall across the basin as a whole. Areas adversely affected by reduced rainfall—the central and southern San Juan Basin—acted as donor areas for population out-migration. Areas less subject to reduced rainfall the Mesa Verde and McElmo regions become recipient areas for immigrants (Scheick et al. 1991:133). Although the central and southern portions of the San Juan Basin were occupied to a limited extent by Mesa Verde elements, many parts of the basin appear to have been abandoned toward the terminal portion of the P III Period.

P III sites are found in the Mesa Verde region, in the Middle Chuska Valley, in the Española, Tesuque, and Santa Fe Basins, in Chaco Canyon and the Lower Chuska Valley, north into the Navajo Reservoir region and south from the Rio Puerco to near Truth-or-Consequences, New Mexico (Marshall and Walt 1984:75, 95; Scheick et al. 1991:128). Sites are found in both riverine and upland areas along the escarpment of the Rio Grande, as well in outlying districts far from major tributaries.

1.2.5.5 Pueblo IV (ca. A.D. 1300 - 1540)

The Pueblo IV Period is typified by yet further movements of peoples into parts of the northern project area, again in response to deteriorating climatic conditions elsewhere in the region. The region around Abiquiu, New Mexico, experienced a decline in settlements toward the end of this period; populations withdrew downstream toward the confluence of the Rio Chama and Rio Grande (Schaafsma 2002:199, 1976; Whitten and Powers 1980:20). As a result, parts of the lower Rio Chama experienced a concomitant increase in the number of late P IV sites, perhaps because more reliable surface water supplies were found in this stretch of the river. At the same time, continued reliance on, and expansion of, rainfall dependent agricultural systems (e.g., bordered fields gravel mulch gardens) suggests that surface water availability was not particularly crucial in settlement decisions during this period (Scheick et al. 1991:135; Whitten and Powers 1980:21).

Sites dating to this period are generally small, containing between 1 and 4 rooms. A minor subset of sites contains 100 rooms, while an even more minor subset of the largest sites exhibit up to 500 rooms. Current notions suggest that the bulk of the region's population resided in larger villages, while smaller sites were used for seasonally-specific gathering of wild plant and animal resources (Scheick et al. 1991:139). This shift was accompanied by a dramatic increase in the appearance of water harvesting structures such as terraces, rock pile grids, gravel mulch gardens, check dams, and small reservoirs. This implies that crop production became more feasible in areas that previously were unsuited for rainfall agriculture (Scheick et al. 1991:139-140).

Major settlements dating to this period are situated primarily in the upper terraces of floodplains along the Rio Chama, Rio Grande, Santa Fe River, Rio San Jose, Rio Puerco, and Rio Salado (Marshall and Walt 1984:135; Schaafsma 2002:199), with rainfall agricultural sites located in adjacent upland areas (Scheick et al. 1991:141-142).

There are pueblos that are likely ancestral to modern Tewa pueblos in the Rio Chama portion of the northern project area. These include Tsankawi, Tsirege, Puye, and Potsuwi'i (Schaafsma 2002:202). Petroglyphs support a Tewa presence in the area around the confluence of the Rio Grande and Rio Chama during late P IV and early historic times (Boyd and Ferguson 1988:5-71).

Protohistoric P IV Navajo occupations are also found in the upper Rio Chama (Schaafsma 2002). Many of these sites were occupied between *ca.* A.D. 1650 and 1710 (Schaafsma 2002:187), suggesting that Navajo occupations may have supplanted Tewa occupations in the Rio Chama at the beginning of the seventeenth century.

1.2.6 The Southern Area (Reaches 13 through 17)

The succeeding periods in the occupational prehistory of the southern portion of the planning area (Reaches 13 through 17) are generally termed *Mogollon*. Archaeological research was first intensively done in the Mogollon area of southern New Mexico and west Texas by Donald Lehmer in the late 1940s. This early research has since served as a baseline for subsequent researchers.

According to the phase sequence first postulated by Lehmer, there was a shift away from nomadic hunting-and-gathering around 2,000 years ago. This shift toward a more sedentary settlement system is reflected in progressively greater emphasis on the cultivation of crops such as maize and beans and may have been prompted by increasing population growth. The phase system defined by Lehmer (1948) postulates a linear increase from simple to more complex strategies and technologies through time. However, recent research has shown that the assumptions of increased complexity inherent in the phase system may be erroneous and that they do not account for much of the variability present in the archaeological record (Kauffman and Batcho 1983, Stuart and Gauthier 1981; Upham 1984).

In the southern New Mexico area, the Formative Period has been subdivided into three phases: the Mesilla (A.D. 900-1100), Doña Ana (A.D. 1100 -1200), and El Paso (A.D. 1200-1400) phases. **Table O-1.7** shows the frequency of components by reach for each of these time period.

The Mesilla Phase is defined by the presence of undifferentiated brownware ceramics and a subsistence base composed of a mixture of hunting and gathering and agriculture (Kirkpatrick et al. 2000:70).

Pithouses and plain brownware ceramics were present in the area from as early years as A.D. 200 (Carmichael 1985; O'Laughlin 1980) so that, in this part of the project area, the Mesilla Phase appears to span the years A.D. 200 to 1100 (Moreno and Hayes 1984; Whalen 1980a). The presence of pithouses and plainware ceramics indicates a more sedentary lifestyle and a greater energy investment in dwelling construction and maintenance.

In most other respects, however, Mesilla phase artifact assemblages and settlement patterns do not appear to have undergone significant modification from those associated with Archaic groups. This may be due, in part, to the possibility of heterochroneity in the adoption and expansion of agriculture among groups across southern New Mexico (LeBlanc and Whalen 1980:451). Toward the end of this phase, large pithouse villages commensurate with increases in population concentration and the presence of purported trade wares consistent with more widespread regional interaction begin to characterize the archaeological record.

Table O-1.7. Summary of Mogollon Phase Occupations in the Southern Project Area

Reach	Mesilla	Doña Ana	El Paso	TOTAL
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	39	26	21	86
15	62	32	31	125
16	395	230	228	647
17	0	0	0	0
TOTAL	496	288	280	858

1.2.6.1 Mesilla Phase (A.D. 400-1200)

Mesilla phase sites have been located in a variety of environmental settings. Sites from this period have been found in riverine settings and at the confluences of tributaries with the mainstem of the Rio Grande (Marshall and Walt 1984:75). At the same time, the availability of permanent water sources seems to have been an important factor in settlement location. The use of domesticated plants continued to be a major subsistence source throughout this phase.

Mimbres Black-on-white ceramics may indicate an interaction with Mimbres Mogollon groups to the west. Additional studies are needed to confirm this tenuous evidence for long-distance trade and interaction.

1.2.6.2 Doña Ana Phase (A.D. 1200-1300)

As proposed by Lehmer (1948), the Doña Ana phase represents a short-lived occupation and transition from the Mesilla to El Paso phases. Both pithouse and adobe pueblos are known from this phase. Doña Ana ceramic assemblages consist of El Paso Brown, El Paso Red-on-brown, El Paso Polychrome, Mimbres Black-on-white, Three Rivers Red-on-terracotta, Playas Red, and Chupadero Black-on-white types (Carmichael 1985).

The number of large sites or pueblos recorded in this phase suggests increasing population and a more structured regional social organization than was previously observed during the Mesilla phase (Whalen 1981). During this phase, the inhabitants of the Mogollon may have been in direct contact with large social networks in northern Mexico (Schaafsma 1979). Sites from this period have been found along the upper terraces of floodplains and adjacent bluff escarpments along the Rio Grande (Marshall and Walt 1984:95).

Large adobe pueblos assigned to the Doña Ana phase are found both in riverine and nonriverine areas of the project area. Although sites dating from this period are usually ephemeral and not well documented, they have been recorded in the Rio Grande valley, the Hueco Bolson, and the Tularosa Basin (Carmichael 1983; Miller 1989; O'Laughlin 1981).

1.2.6.3 El Paso Phase (A.D. 1300-1450)

The El Paso phase represents the terminal portion of the Mogollon phase sequence in the southern part of the project area (Kirkpatrick et al. 2000:77). Architecture consists of above-ground, linear-roomed adobe pueblos (Kirkpatrick et al. 2000:77). Site locations are varied, but alluvial terraces and playa margins appear to be preferred settings for sites of this period. The ceramic assemblage is also varied and contains El Paso Polychrome, Mimbres Classic Black-on-white, Chupadero Black-on-white, Three Rivers Red-on-terracotta, Gila and Tonto Polychrome, and a variety of Chihuahuan wares.

Agricultural pursuits may have intensified during this phase, partly in response to increased population growth. Maize, beans, squash, and bottle gourds were the primary domesticated plants (Ford 1977). The continuing recovery of wild plant and animal resources from El Paso phase sites suggests that the production of domesticated crops had to be augmented with wild resources. Varieties of Zea having different maturation rates may have been grown in different environmental zones (Stuart and Gauthier 1981:218; Mauldin 1986).

Regional interaction during this phase reached a maximum, best indicated by the presence of nonlocal ceramics, such as Mexican Polychromes and Tucson Polychrome (Elyea 1987:37-38). Regional interaction is also seen in the presence of ornaments manufactured from marine shell originating from the Pacific and Gulf Coasts and copper bells from Mexico (Duran 1984; LeBlanc and Whalen 1980:382; Lehmer 1948; Stuart and Gauthier 1981:214).

Chipped stone and groundstone assemblages from the last two phases of the Formative Period underwent significant modifications. Groundstone expanded to include slab, basin, and trough varieties. Lithic assemblages included locally obtainable materials and centered around the production of expedient tools and flakes (Anyon and LeBlanc 1984; Chapman 1977; Laumbach 1980b). In general, projectile points were much smaller and even more varied during this phase.

Sites from this time period are located in a variety of settings including riverine and bluff escarpments adjacent to the Rio Grande (Marshall and Walt 1984:137). Studies further south have found sites of this period situated in nonriverine bolsons located north of El Paso.

The Formative Period is thought to end around A.D. 1400-1450. Causes underlying the abandonment of southern New Mexico remain obscure.

1.3 HISTORIC PERIOD

As with its prehistory, the character of Historic Period occupations varies considerably between the northern and southern parts of the planning area. Beginning with the arrival of the earliest Spanish explorers in 1598; the northern reaches of the Rio Grande remained occupied through the Spanish Colonial, Mexican, and Euro-Anglo Periods. In contrast, much of the southern project area was not occupied until the close of the Mexican Period and settlements did not really expand until after 1848 with the arrival of Euro-Anglo settlers. For this reason, the discussion of the Historic Period is divided into the northern and southern portions of the project area.

1.3.1 The Northern Area (Reaches 1 through 12)

There is overlap between events that occurred during the preceding Navajo Historic Periods and events more closely associated with Euro-Anglo occupations of the project area. While reference is made to related Navajo events, the primary focus of this section is on events related to post-contact (i.e., A.D. 1540) Euro-Anglo activities. This general period, in turn, is segmented into Spanish, Mexican, and Euro-American Periods.

1.3.1.1 Spanish Period (A.D. 1540-1821)

In the northern reaches of the planning area, the earliest evidence of Spanish entry (*entrada*) into New Mexico is associated with the appearance of Coronado's expedition in 1540 (Winship 1990). Initial contacts with the inhabitants were not promising insofar as the Spaniards, prompted by reports of great wealth, viewed the region's inhabitants as potential sources of wealth (Winship 1990:18). Greeted by showers of arrows at some pueblos, Coronado's men soon found that reports of gold were overstated (Winship 1990:46). In 1542, after smaller expeditions into the surrounding country revealed no great wealth, Coronado's expedition withdrew to Mexico (Scurlock 1998:106). Other expeditions, including those of Chamuscado-Rodriguez (1581), Espejo (1583), Costaño (1590), and Bonilla-Humaña (1593), penetrated New Mexico territory but did not stay for any length of time (Bartlett 2002:5; Hammond and Rey 1938:20-25).

Spanish Conquistadores first visited New Mexico's lower Rio Chama Valley in the summer of 1541 when followers of Francisco Vásquez de Coronado explored the region. Anticipating a need for winter supplies, the foraging party intended to requisition grain stockpiled by pueblo farmers. At the junction of the Rio Grande and the Rio Chama, Barrionuevo camped at Yuque-Yunque, a Tewa community composed of two villages, divided by the Rio Grande. When horsemen approached them, the Indians fled toward the Rio del Oso, a tributary of the Chama, and took refuge in "four strong towns," inaccessible to mounted men because of the rugged terrain. Given a free hand, the intruders helped themselves to the provisions stored in the deserted villages before continuing on to Taos (Bolton 1949: 309-10). Discouraged by failure to find gold and silver or other riches after extensive explorations, Coronado's expedition returned to New Spain in the spring of 1542.

After Barrionuevo's brief entrada, almost fifty years passed before Spaniards returned to the confluence of the Chama and the Rio Grande. At the end of December 1590, a party of adventurers commanded by Gaspar Castaño de Sosa arrived at the great Pueblo of Pecos, ending an arduous journey from the province of Nuevo León in New Spain. Misguided from the outset, Castaño's followers hoped to settle in New Mexico, but lacked authorization from officials in New Spain. After receiving a chilly reception at Pecos, an advance guard pushed on for a reconnaissance of the Tewa villages to the northwest. Despite deep snow and frigid temperatures, the Spaniards spent ten days among the Tewas, beginning with the pueblos of Tesuque, Cuyamungué, Nambé, Pojoaque, and Jacona. Castaño's scribe observed with surprise that all these small communities raised bountiful crops that were irrigated from the Tesuque and Pojoaque rivers. The party proceeded to San Ildefonso on the Rio Grande and then continued upstream to Yuque-Yunque and the Tiwa village of Picurís. After returning to Pecos, the adventurers moved their camp to Santo Domingo. There, representatives of the viceroy arrested Castaño for illegal entry into New Mexico and took him back to Mexico City in chains (Schroeder and Matson 1965: 117, 172-75).

When Spaniards next returned to northern New Mexico, they came to stay. In 1598, Juan de Oñate led a large expedition out of Santa Bárbara in present Chihuahua to found a permanent colony on New Spain's farthest frontier. On January 8, Oñate's followers set out—129 citizen soldiers, many with families, accompanied by ten Franciscan friars, and a large number of Mexican Indian auxiliaries, an assortment of livestock, pack animals, baggage carts, and supply wagons. By July 11, the vanguard had ascended the Rio Grande as far as Ohke, one of the twin villages visited by Barrionuevo in 1541. Renamed "San Juan Bautista" in honor of Oñate's patron saint, the east-bank town of Ohke became temporary headquarters for the expedition. Situated on a fertile flood plain near the confluence of the two rivers, the location seemed to be well chosen. To celebrate Roman Catholic services, an interim church was soon erected; dedication ceremonies took place on September 8, birth date of the Blessed Virgin (Hammond and Rey 1953: 14-17; Kessell 2002: 78).

Overcrowded and unsanitary, Ohke soon proved to be unsuitable for the colonists. Since they had failed to build new quarters for themselves, the colonists persuaded the Tewas to evacuate Yuque-Yunque, the village on the west bank. Sometime before Christmas 1600, the Tewas moved across the river into the new location that Oñate called "San Gabriel" (Ellis 1987: 10-39). The settlers lost no time in establishing farmlands and an irrigation system. In letters to the viceroy and others, Oñate reported bountiful harvests of wheat, maize, and other crops. His enthusiasms seemed to be confirmed by a visiting ecclesiastic, Fray Juan de Torquemada (1723, reprint 1975: 672), who described agricultural production at the new colony as follows: "San Gabriel is situated between two rivers, and with water from the smaller [the Chama], they irrigate wheat, barley, maize, and other things that they plant in gardens." Cattle and sheep imported from New Spain yielded beef and mutton and also provided wool for textiles and hides for leather goods.

Crop production seemed to be proceeding nicely in the colony, but Oñate's overly optimistic reports ignored the deep discontent spreading among the settlers. Accustomed to an urban existence, many of them were unable to cope with the rigors of life on the frontier. Complaints of food shortages and mistreatment of native people began to reach authorities in New Spain. During the summer of 1601, while Oñate explored the vast buffalo plains far to the east, four hundred men, women, and children gathered their belongings and fled from San Gabriel. Once the refugees had made their way to Santa Bárbara, officials in Mexico City launched a lengthy investigation into Oñate's conduct as governor of New Mexico. After considering testimony from the adelantado's friends and foes, agents of the king decided that New Mexico would not be abandoned. No mines or other sources of wealth had been discovered, but Franciscan friars related that they had baptized several thousand Indian converts. Although the report was greatly exaggerated, King Phillip III ruled that the colony would be maintained by royal subsidies to support the missionary program among the indigenous population (Kessell 2002: 85-86, 94-95).

The decision failed to vindicate Oñate, however. Tired and discouraged, he resigned his position as governor on August 24, 1607, and subsequently returned to Mexico City. As his replacement, the king chose Pedro de Peralta, an experienced civil servant, who arrived early in 1610 to serve a three-year term as New Mexico's governor. Acting on orders from the viceroy, Peralta immediately laid out a new capital city, to be known as "La Villa de Santa Fe," which represented a new beginning for the troubled province. Located about twenty-five miles south of San Gabriel on the west slope of the Sangre de Cristo Mountains and, unoccupied by Pueblo Indians, the town site adjoined a reliable stream and was well endowed with timber and pasture. After he had selected an appropriate position for a central plaza and public buildings, the governor distributed lots for houses and gardens to each citizen. According to Spanish law, every resident was also entitled to sufficient farmland to sustain his family, with water for irrigation. Once the new villa had been established, the colonists abandoned Oñate's old headquarters at the junction of the Rio Grande and the Chama (Kessell 2002: 95; Hammond and Rey 1953: 1085-88).

At the time of first Spanish contact, there were—according to Spanish chronicles— at least 93 pueblos located along the Rio Grande between Taos and Socorro (Bartlett 2002:10, 25, 45). Most were located along the margins of the Rio Grande floodplain (Bartlett 2002:10). The exact locations of many of these pueblos is uncertain, although a comprehensive index of named places has been extracted from Oñate's chronicle (Hodge 1935), as well as from other sources (e.g., Bartlett 2002:19, 23, 25; Marshall and Walt 1984:235-287). There were also many other pueblos along major tributaries of the Rio Grande. These included (Bartlett 2002:22-23, 33-44, Table 11):

- 1. Acoma along the Rio Puerco.
- 2. Santa Ana, Zia, Unshagi, Nanishagi, Guisewa, Kiatsukwa, Seshukwa, Amoxiumqua, Kwastiyukwa, and Tovakwa along the Rio Jemez.
- 3. Cochiti, Santo Domingo, La Bajada/Talaván, Gipuy, La Vega, Katishtya, Old San Felipe, and Tunque in the Santo Domingo Basin.
- 4. Paa-ko, San Antonio, and Silva in the Sandia region.
- 5. San Marcos, San Lazaro, Galisteo, and San Cristóbal in the Galisteo Basin.
- 6. Chilili, Tajique, Quarai, Abó, Tenabo, Pardo, Blanco, and Colorado in the Estancia Basin.

Archaeological investigations, particularly at Cochiti Reservoir, have encountered still other pueblos dating to the 1525-1539 contact period (Biella and Chapman 1977:14-128), suggesting that the extent of contact-period occupations may be much greater than that indicated by documentary sources alone.

In the years immediately following Oñate's arrival, the capital was moved to Santa Fe and outlying settlements established to the north near at Taos, near San Juan Pueblo and in the Santa Cruz de la Cañada and to south near Bernalillo and Socorro (Espinosa and Chavez 1966:8-9). Missions were also established at Socorro (1626), Abo (1629), Gran Quivira, Quarai, Chilili (1629), and Tajique (1629), although many of these places were abandoned by 1677 due to persistent raiding from the east (Espinosa and Chavez 1966:11).

Explorations of areas to the west of Santa Fe by Saldivar in 1618 encountered the Hopi and went as far as the upper reaches of the Colorado River (Shea 1964:78-79). Expeditions to the east, notably that undertake by Peñalosa in 1662, found Plains Indians and the buffalo ("cows of Cibola") on which they depended (Hammond and Rey 1953:484, Schaafsma 2002:210-211, Shea 1964:58). In no case were conditions such that the Spanish contemplated establishing permanent settlement in these regions.

Traveling through much of New Mexico, Benavides, in his 1630 narrative, provided the most accurate descriptions of the tribes that inhabited various parts of the state. Between Oñate's arrival in 1598 and the mid-1600s, the overall number of pueblos in the middle Rio Grande near Albuquerque declined from 23 to about 15 to 16 (Bartlett 2002:61-62). In the Estancia Basin, the number of occupied pueblos declined from 11 to six (Bartlett 2002:62). By 1643, the overall number of pueblos had declined from 93 at the time to contact to only 38 (Bartlett 2002:62). Bartlett speculated that this decrease may have been due to the combined effects of (a) inter-pueblo strife; (b) the deleterious effects of the encomienda system whereby tribute (e.g., goods and labor) were forcibly obtained from the pueblos; (c) usurpation of pueblo lands by Spanish colonists; (d) disruption of trading relations whereby agricultural goods from the pueblos were exchanged for meat obtained by Plains tribes (Bartlett 2002:60, 68-72), and Apache raiding, which intensified throughout the 1600s (Bartlett 2002:72-74; Scurlock 1998:41). By the 1670s, the pace of pueblo abandonment had accelerated considerably. All of the pueblos in the Estancia Basin had been abandoned, as had the pueblos in the southern reach of the project area (Bartlett 2002:63, 65).

There is relatively little documentation regarding Spanish activities in the region between 1610 and 1680 (Bandelier and Hewett 1978:133). There were only scattered Spanish settlements during the seventeenth century in the project area, with populations concentrated at the towns of San Gabriel, Santa Fe, Cienega, Bernalillo, Atilxco, and Varela [Barelas] (Scurlock 1998:108). Most of these settlements were concentrated along the Rio Grande corridor, with a few settlements extending into the lower reaches of major tributaries of the Rio Grande (Williams 1986). Others, such as Santa Rosa de Lima de Abiquiu—situated downstream from the modern town of Abuquiu—were occupied after 1692, but were abandoned in 1740 due to raiding (Weigle 1975:154; Whitten and Powers 1980:24). By 1782, raiding along the frontier throughout this period caused the partial or complete abandonment of some outlying towns—notably Pecos, San Marcos, San Lazaro, San Pedro, and San Cristobal—with the populations taking refuge in larger, more well-protected towns such as Santa Fe (Morfí in Thomas 1932:91, 93, 96).

Activities during this early period seem to have focused primarily on ranching, with officers being allotted large parcels (*estancias*) situated between what is today Española and Albuquerque (Carlson 1990:6). The advent of encomienda practices, by which Spaniards were entitled to the use of Indian labor and access to goods produced by them in return for protection from raiding, caused large parcels to be concentrated in the hands of a few landowners (Knaut 1995:62-64, 66-68; Weber 1992:124-125). According to Benavides, the usual tribute paid by the Indians was one cotton *manta* (man's shawl or blanket) and a *fanega* (approximately 2.6 bushels) of corn per house (Ayer 1965:23; Bartlett 2002:68-69; Weber 1992:125). In being subsidized by the Indians, all impetus for Spanish self-sufficiency was removed (Carlson 1990:6).

Because property records were almost completely destroyed in the Pueblo Revolt of 1680, information concerning the pattern of Spanish settlement in seventeenth-century New Mexico is limited. Church documents indicate, however, that by the mid-1620s, a few hardy frontiersmen had begun farming at "La Cañada," a river valley about twenty miles north of Santa Fe. Later called the Rio Santa Cruz, the river flowed west from the Sangre de Cristos, meeting the Rio Grande at present Española. Consisting of scattered ranchos, the Cañada community eventually extended up the Santa Cruz as far as Chimayó and down the east bank of the Rio Grande toward the Pueblo of Pojoaque. Early settlers included Juan Griego, who had passed muster with Oñate in 1598, and Pedro Márquez, a young officer at the Santa Fe presidio. Both claimed lands near the Pueblo of San Juan (AGN, Inquisición, 304, f. 186; 372, f. 7). Further downstream, across the Rio Grande from San Ildefonso's Black Mesa, some six or seven estancias (small ranches) had been established by mid-century. Prominent among the owners was Francisco Gómez Robledo, one of New Mexico's most affluent citizens, who owned lands in several parts of the colony. In 1662, church authorities accused Gómez of "Judaical tendencies" and confiscated all of his assets pending trial. After lengthy proceedings in Mexico City, he was cleared of all charges. He returned to New

Mexico and reclaimed the sequestered lands and personal property (SANM I: 882, ff. 2-3, 8-12; Chávez 1954: 36).

Although settlement east of the Rio Grande is fairly well documented, colonial archives reveal only one instance of settlement on the opposite bank during this period. Early in the eighteenth century, after the Reconquest of New Mexico, Antonio de Salazar petitioned Governor Juan Ignacio Flores Mogollón for lands west of the river at Corral de Piedra, a site located a few miles below the Rio Chama junction. According to Salazar, the tract requested had been granted previously to his great-grandfather, Captain Alonso Martín Barba, one of the original Oñate colonists (SG 132, Antonio de Salazar Grant). Scattered sources suggest that permanent occupation in the Chama Valley was curtailed by hostile Navajos, who began stealing livestock and harassing colonists at San Gabriel before the founding of Santa Fe (Worcester 1951: 103-4).

After the arrival of newcomers from Mexico City in 1694, Vargas decided to strengthen his northern frontier by founding a new community at La Cañada, a river valley about 20 miles north of Santa Fe. Abandoned in 1680, the valley had been partially occupied by Tano Indians from Galisteo during the Spanish hiatus. With great fanfare, the governor issued a decree on April 19, 1695, announcing plans to create a town grandly identified as "La Villa Nueva de Santa Cruz de La Cañada de Españoles-Mexicanos del Rey Nuestro Señor Carlos Segundo." Two days later, he personally escorted some sixty families out of Santa Fe to a site on the south side of the Rio Santa Cruz. There, he laid out a plaza and conducted the traditional possession ceremony. After placing Fray Antonio Moreno in charge of a makeshift chapel, Vargas appointed officials for the administration of civil and military affairs. Before departing, he ordered that each family receive sufficient land to plant one-half fanega of maize (approximately 4.4 acres). Once established, Santa Cruz de la Cañada became the center of government for northern New Mexico and served as the starting point for future settlement along the upper Rio Grande and the Chama Valley (Kessell et al. 1998: 617-24).

Two years after Vargas founded the new villa, New Mexico experienced an important change in administration. On July 2, 1697, Don Pedro Rodríguez Cubero, a Spanish-born bureaucrat, arrived in Santa Fe to take office as governor of the province. As chief executive, Rodríguez Cubero made several land grants south of Santa Cruz de la Cañada in the Pojoaque Valley. Some were situated near the Tewa villages of Pojoaque and Jacona, which had been abandoned in 1696 during the last phase of pueblo resistance. The governor also approved grants further west along the Rio Grande that encroached on lands claimed by the pueblos of San Ildefonso and Santa Clara. In the spring of 1700, José Trujillo, a native New Mexican soldiering at the Santa Fe presidio, received a large tract east of the Rio Grande suitable for irrigation. Bounded north and south by Arroyo Seco and the *mesilla* of San Ildefonso, the lands had been occupied before 1680 by Francisco Gómez Robledo, Ambrosio Saiz, and Francisco Jiménez (Twitchell 1976: 331, 336). At about the same time, Rodríguez Cubero was handed a similar petition for a grant on the west bank from Mateo Trujillo, a pre-Revolt settler who had narrowly escaped death in 1680. In 1702, Matías Madrid asked for a third grant impinging on San Ildefonso at the site of present-day El Rancho. Rodríguez Cubero approved all three, but subsequently, the Indians at San Ildefonso and Santa Clara frequently disputed boundary locations with the successors to the original grantees (Jenkins 1972: 122-29). South of the Rio Pojoaque, no Hispano settlement took place along the Rio Grande until the mid-eighteenth century.

The *encomienda* system imposed significant burdens on Rio Grande pueblos and, combined with a succession of years that saw low rainfall and high temperatures and accelerating attacks from both Navajo and Plains tribes, culminated in the Pueblo Revolt of 1680 (Bartlett 2002:74-77; Knaut 1995:156-162; Sando 1979; Scholes 1937:99-100; Weber 1992:133-136). Although there had been rebellions in 1639, 1650, and 1667, the 1680 revolt was unusual in that, for the first time, most of the pueblos were able to effectively coordinate simultaneous uprisings, led initially by Popé, from San Juan Pueblo (Ortiz 1979:281). The small number of Spaniards was insufficient to prevent the rout and the colonists were forced to withdraw to El Paso, leaving some 400 dead behind (Weber 1992:135; Knaut 1995:133-134). To make matters worse, the revolt in New Mexico presaged far more widespread uprisings, lasting through much of the 1680s, that eventually extended to include indigenous peoples of Coahuila and Sonora (Espinosa 1988:80; Weber 1992:137).

As a consequence of the results, there is almost no information about the intervening years between the 1680 Revolt and the 1692 Reconquest (Bandelier and Hewett 1978:128-129). Scholars have concluded that, aside from expunging all traces of Spanish political and religious institutions, the pueblos largely continued the economic activities of farming and ranching that had typified pre-Revolt times (Forbes 1960:189).

Figure 1. The Camino Real

One notable exception to this dearth of information was the development of El Camino Real de Tierra Adentro, the Spanish Royal Road that connected Mexico City with the far-flung colonies in New Mexico (**Figure O-1**). Situated at the end of a long supply line, one of the first tasks that befell the Franciscan missionaries was to make supply trains into New Mexico routine. In 1631, contracts were drawn up specifying that supply trains would consist of 32 wagons driven by 32 freighters and accompanied by Indian scouts and cooks, as well as military escorts of varying size (Ivey in Palmer1993:42-67). These trains traveled back and forth between Santa Fe and Mexico City every 18 months; the journey across the 1600 mile distance usually took about six months (Ivey in Palmer 1993:45). During the Pueblo Revolt of 1680, the Camino Real became the main route by which Spanish colonists and their Indian allies fled to escape to El Paso (Hendricks 1993). Once El Paso became the staging ground for Vargas' efforts to re-conquer the region (1692), the Camino Real became the main route for his expedition's travel northward.

The Camino Real remained one of the primary supply and communication routes in New Mexico well into the nineteenth century (Schroeder 1993). Following the Rio Grande, the Camino Real passes through the entire planning area. Moreover, it has recently been designated as a National Historic Trail. Although its precise location relative to the project boundaries remains uncertain, it is nonetheless an important property whose historic significance to New Mexico is without parallel.

In 1692, a new governor, Diego de Vargas led an exploratory expedition up the Rio Grande to persuade the pueblos to accept Spanish sovereignty once more. During a four-month tour, Vargas visited all the pueblo villages and secured submission by combining bravado with diplomacy. After he returned to New Spain, royal officials applauded Vargas' peaceful reentry, but his triumph proved ephemeral. When he arrived the following year with settlers to restore the colony, he encountered widespread resistance. Santa Fe was soon recaptured, but sporadic fighting continued until 1696. Undaunted, the governor launched a comprehensive program to rebuild New Mexico while hostilities persisted in some localities. Realizing that the colony needed additional settlers for survival, Vargas recruited families in Mexico City and Zacatecas willing to emigrate far to the north (Jenkins and Schroeder 1974: 22-23).

The Pueblo Revolt of 1680 and the 1694 and 1696 rebellions that followed Vargas' 1692 re-conquest of New Mexico were accompanied by the relocation of the inhabitants of some Rio Grande pueblos (Espinosa 1988:50-51; Weber 1992:139). For example, during this period Tanoan-speakers from some Rio Grande pueblos moved to Hopi, eventually forming the separate Pueblos of Payupki and Hano in that country (Bartlett 2002:93-94; Brant 1979:354; Brew 1979:522; Schaafsma 2002:294; Weber 1992:140). Others from the northern reaches of the project area took refuge for a while at Taos Pueblo (Bartlett 2002:113). Some residents from San Felipe and Cochiti also abandoned their pueblos, fleeing to Horn Mesa until 1692 (Strong 1979:393). Some residents of Picurís and nearby pueblos also left, heading east to join Apache (Plains) settlements in Kansas (Bartlett 2002:106; Brown 1979:271; Hackett 1937:374; Knaut 1988:126; Weber 1992:140). Elements from other pueblos fled west, taking refuge with the Navajo in the headwaters of the Rio Chama (Bartlett 2002: 110-111; Kessel et al. 1998:1001-1028; Knaut 1988:210) or among the residents of Zuni and Acoma (Schaafsma 2002: 295). Indeed, Laguna Pueblo was founded between 1697 and 1699 by refugees from other Rio Grande pueblos (Ellis 1979:438; Forbes 1960:265-267) and portions of Old Zuni were abandoned (Woodbury 1979:472). The residents of Pojoaque also scattered and the pueblo was not resettled until 1706 (Lambert 1979:325). Despite these moves and the passage of centuries, it is plausible that many descendants of those who fled their homelands continue today to maintain connections with pueblos in the Rio Grande Basin.

Following on the heels of the gradual withdrawal of Navajo elements from the Rio Chama Basin (Schaafsma 2002:303), Spanish settlements began to appear in the Rio Chama Basin, first at Chamita in 1714 (Schaafsma 2002:303; Swadesh 1974:32; Whitten and Powers 1980:23). Settlements gradually extended upstream along the Rio Chama during the 1730s with the founding of Abiquiu (1734), Barranca (1735), Plaza Colorada (1737), Plaza Blanca (1737), Lobato (1744), Ojo Caliente (1754), Cañon de Chama (1806) and other small villages (Brayer 1949:253; Swadesh 1974:33-39). Although these settlements were briefly abandoned between 1747 and 1750 due to raids, they were eventually resettled and have continued to be occupied for many years (Swadesh 1974:36-37). At the beginning of the nineteenth century, population growth leading to land scarcity caused additional land grants to be made at San Joaquin (1808), Vallecito (1807), and Tierra Amarilla (1814, but not finalized until 1832) (Swadesh 1974:49-50).

Spanish activities during the eighteenth century focused primarily on consolidating their holdings in the Rio Grande valley. During this period, pre-Revolt land grants were reaffirmed and new land grants were awarded (Williams 1986:105; Scurlock 1988: Table 34). Land grants to all of the pueblos along the Rio Grande—Taos, San Juan, Santa Clara, San Ildefonso, Tesuque, Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, and Isleta—were reaffirmed and residents who had fled possible Spanish retributions were encouraged to return (Brayer 1939). A general trend surface map showing time-sequent expansion of Spanish and Mexican land grants is shown in **Figure O-1.2**.

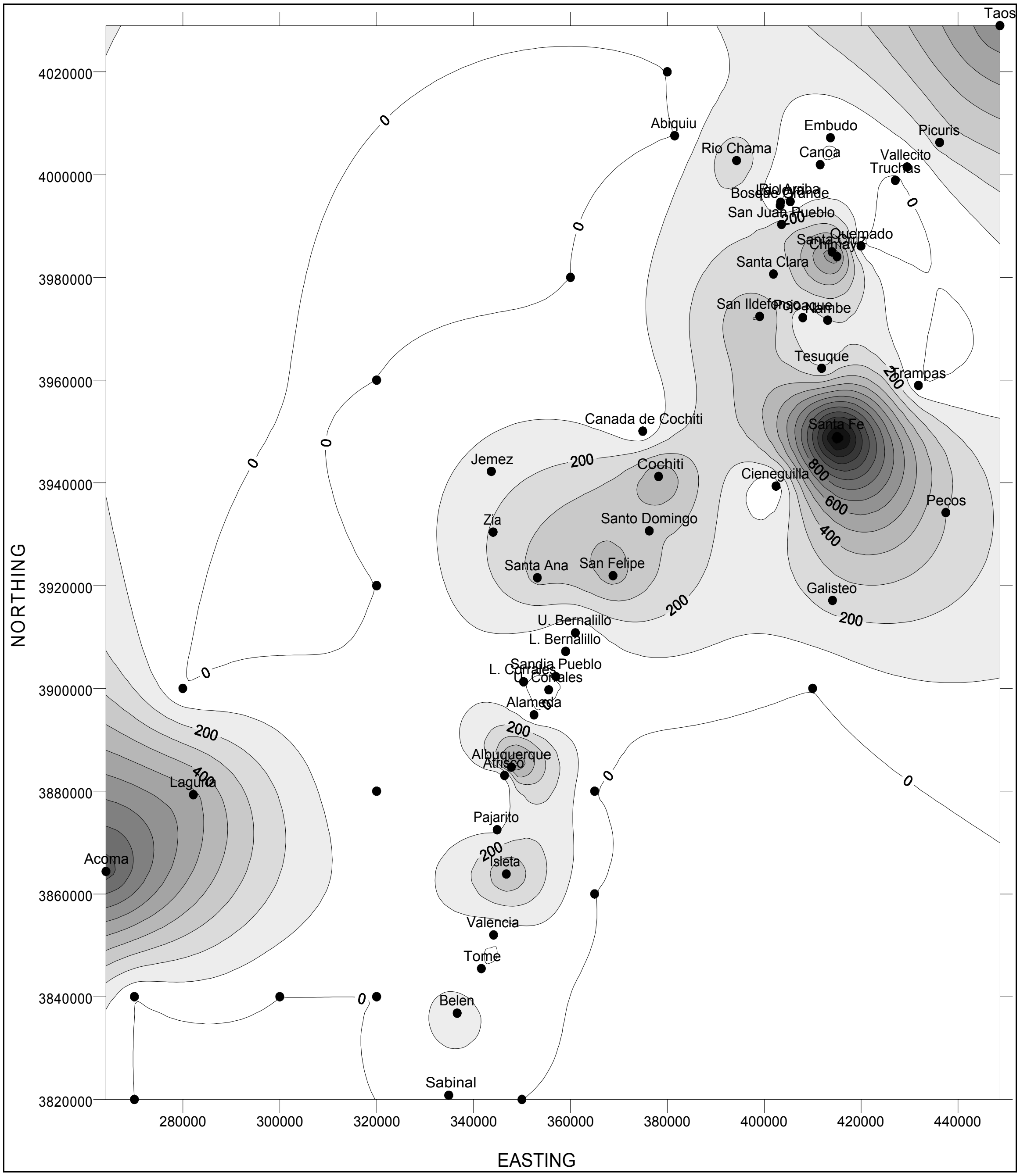


Figure O-1.2. Population Distribution in 1750.

Elsewhere along the Rio Grande mainstem, numerous land grants were awarded to settlers at such recognizable localities as Cieneguilla (1693), Bernalillo (1701), Albuquerque (1706), Alameda (1710), Ignacio de Roybal (1702), Plaza Colorado (1739), Plaza Blanca (1739), Tomé (1739), Belen (1740), Cañada de Cochiti (1740), Los Luceros (1742), Black Mesa (1743), Trampas (1751), Abiquiu (1754), Polvadera (1766), Piedre Lumbre (1766), Santa Cruz (1767), San Ysidro (1786), Los Cerillos (1788), Ojo Caliente (1793), and San Fernando de Taos (1799) (Brayer 1949:161; Julyan 1996; Williams 1986:105). There were three types of land grants during this period: grants to individuals, community land grants given to ten or more Spanish families or to specific pueblos, and sitio (ranch) grants ranging from 4326.4 to hundreds of thousands of acres (Schutt and Chapman 1992:36). Further south, in the Rio Puerco Basin, Spanish settlements (*ranchos*) were established in 1753, but were abandoned by 1774 due to Navajo raids (Widdison 1958:56). Most of the grants awarded during post-Revolt times were either individual or community land grants.

According to a trend surface map showing time-sequent appearance of Spanish and Mexican land grants (**Figure O-1.3**), the earliest Spanish Colonial grants are concentrated in the Rio Grande valley. Later Mexican period land grants are located along the southern and eastern periphery of the state.

Throughout Spanish Colonial times, sheep raising was one of the primary economic activities since sheep provided wool for clothing, tallow for candles, and meat for consumption (Carlson 1969:26; Morfí in Thomas 1932:111). Sheep production in New Mexico was promoted, in part, due to the high demand for meat at Spanish mines in northern Mexico, notably the Durango and Viscaya regions (Carlson 1969:26). This high demand also acted as a catalyst for the appearance of new settlements in areas suited to sheep raising. Drives occurred annually down the Camino Real, with nearly 40,000 sheep being delivered to Spanish mines in northern Mexico (Baxter 1993:105-109; Carlson 1990:79). In addition, since much of the Spanish economy operated on the barter system, sheep came to be used as a medium of exchange over much of the state (Carlson 1969:26; Morfí in Thomas 1932:113; Weber 1992:196).

Despite the presence of so many settlements, the overall population of the northern reach of the planning area remained quite small through the eighteenth century (Weber 1992:195). The 1750 census (Olmstead 1981), summarized in **Figure O-1.2**, shows that most villages consisted of fewer than 300 people and only a few villages—notably Santa Fe—exceeded 1200 people. With the exception of the outlying pueblos of Pecos, Acoma, and Laguna, most settlements were restricted to the mainstem of the Rio Grande basin and its major tributaries.

As before, New Mexico's post-Revolt economy depended largely on subsistence farming and livestock production. To make land available for a growing population, colonial officials adopted a well-defined procedure to make grants from the royal domain to worthy citizens as individuals or in groups. Landless persons began the process by submitting a petition for a specific tract to the governor, who then ordered an investigation by the local alcalde. If no adverse claim resulted, the governor gave his approval and directed the alcalde to assemble the grantees and place them in possession of the lands. In community grants, each family received a parcel of irrigated farmland and a house lot facing an enclosed plaza. Every grantee enjoyed access to a large area of commons for grazing animals and collecting wood for heating or construction. By establishing new settlements on the margins of the colony, governmental officials hoped to extend hegemony and prevent incursions from hostile tribes (Westphall 1983: 17-19).

To the northwest of Santa Cruz, one of the ubiquitous Trujillos initiated attempts to settle lands across the Rio Grande beside the Rio Chama. In January 1701, Diego Trujillo made an appeal to Rodríguez Cubero for an unoccupied tract para laborear y fabricar casa para vivir (to farm and build a house to live in). Located close to the former site of San Gabriel in the Yuque-Yunque cañada, the property extended upstream from the junction of the two rivers to the narrows west of San Juan Pueblo, including the present communities of Hernández and El Duende. Noting the adjacent pastures must remain in common, the governor assigned a generous four fanegas of planting land to the grantee, but no possession ceremony took place because of Trujillo's sudden death (SANM I: 926). After his demise, no one occupied the lands for some years, although other settlers coveted the same location. On July 27, 1707, Sergeant Bartolomé Sánchez, a presidial soldier, requested vacant land north of Santa Clara's boundary "at the place called Zhama." Ignoring a large overlap with Trujillo's concession, Governor Francisco Cuervo y Valdés acquiesced, but military duties prevented occupation by Sánchez (SANM I: 824).

Trujillo's heirs failed to protest, probably because neither family had established residence. Thus, settlement was delayed, but not for long.

Early in 1710, six family heads from Santa Cruz de la Cañada asked for lands in the same area previously awarded to Trujillo and Sánchez. At first, a new governor, the Marqués de la Peñuela, gave tentative approval, but later changed his mind after a protest from Sánchez. The decision outraged the petitioners, then increased to ten, who complained that their greater numbers would provide a more effective barrier to Indian attacks than a single family. Officials in Santa Fe remained obdurate, however, fearing that the departure of so many defenders would seriously weaken the villa of Santa Cruz.

Policy changed with the arrival of a new governor, however (SANM I: 1020). In May 1714, Diego Trujillo's heirs asked for revalidation of the four-fanega grant made in 1701 on behalf of Salvador Santistevan and Nicolás Valverde, veterans of the Reconquest. The new executive, Governor Juan Ignacio Flores Mogollón, obliged and authorized Sebastián Martín, the Santa Cruz alcalde, to perform a possession ritual, which took place on August 8 (SANM I: 926). Later in the same month, Flores Mogollón received petitions from more potential settlers, including Antonio Salazar and Antonio Trujillo, son of Diego. The former asked for his great-grandfather's lands at Corral de Piedra, as discussed above; Trujillo wanted a tract lying within the fork formed by the two rivers that later became known as the "Town of Chamita Grant." Eager to promote agricultural development, the governor approved all the requests (SG 132; 36, Town of Chamita Grant). Evidently, the grantees had already taken out an acequia from the Rio Chama (the present Hernández ditch), suggesting that they expected little opposition from Flores (SANM I: 167). Curiously, none of the grant documents mentioned those lands claimed by Bartolomé Sánchez.

Gradually, land-hungry frontiersmen pushed the line of settlement up the Chama Valley. Although original documents are missing, officials apparently made another grant near the present village of Chili to Juan de Mestas in 1715. A native of Santa Fe who had returned to New Mexico with Vargas, Mestas had previously obtained lands at Jacona from Governor Rodríguez Cubero, but sold them before moving north. Located above the grants authorized by Flores Mogollón, his Chama lands lay near the junction of the Rio del Oso, the Rio Ojo Caliente, and the main stream. Soon after arriving, Mestas was drawn into a lengthy dispute concerning land titles that involved all the recent grantees. Trouble arose in November 1715, when the absent Bartolomé Sánchez made a deal with Captain José Trujillo, the Arroyo Seco rancher, to pasture stock on the tract claimed by Sánchez. Charging trespass, the grantees appealed to Flores, who ordered Trujillo off the lands, but suddenly, Sánchez reappeared to file trespass charges of his own. Hoping for a settlement, the governor directed all of the parties to present their grant papers for inspection, but the issue was not resolved for several years until a change in administration took place (SANM I: 167, 834). In 1722, Governor Juan Domingo Bustamante, a strong executive, decreed a partition in which the Chamita grant was confirmed to Antonio Trujillo, Antonio Salazar retained his ancestral lands at Corral de Piedra, and the Sánchez heirs received part of the grant claimed by Bartolomé, then deceased (SG 36, 132). Disposition of the other interests was not recorded, although the Mestas family managed to retain their lands.

Governor Juan Domino Bustamante encouraged new settlement during his tenure as governor. In 1724, he ceded a huge tract adjoining the Mestas property to Cristóbal Torres, a former alcalde mayor of Santa Cruz, who had served in the military for forty years. Stretching up the valley towards Abiquiú, the lands were bounded on the north by the Sierra de las Grullas beyond today's El Rito, and on the south by Santa Clara peak in the Jémez range. After he had received possession, Torres invited other families to inhabit his lands as protection against raids by hostile Utes and Comanches. Working together, they plowed fields, planted wheat and corn, and dug acequias to water their crops. All shared equal rights in the grant as long as they remained on the land. To maintain manpower for defense, the settlers agreed to sell only to outsiders, thus preventing property consolidation and population decline (SANM I: 943, 950).

Unfortunately, continuing Indian harassment caused the little settlement to disintegrate after Cristóbal Torres died sometime in the winter of 1726-27. Within a few years, however, some of the Torres heirs wished to return. In August 1731, Diego Torres and Bartolomé Trujillo petitioned Governor Gervasio Cruzat y Góngora for revalidation of their grant. They demanded that the other landholders join them in reestablishing the community or forfeit all property rights, but their efforts proved premature. Most of the settlers decided not to return and relinquished their titles. On November 24, 1733, the governor ordered the alcalde of Santa Cruz to post a decree that restored the lands to the royal domain and made them available for settlement by others. Deeply disappointed, the Torres heirs refused to give up and continued to pressure officials in Santa Fe. Unmoved, Cruzat y Góngora ignored their pleas, possibly because of the grant's enormous size (SANM I: 943).

Despite official opposition, Bartolomé Trujillo initiated a new strategy to recover a portion of the Torres grant in the summer of 1734. Together with nine other household heads, he petitioned the governor for small pieces of irrigable land (*tierras de pan llevar*) along the Chama at Abiquiú. Surprisingly, Cruzat y Góngora agreed and ordered that each of the ten settlers receive possession of parcels ranging in size from 1 to 2½ fanegas. Most of the plots were located in a row south of the river, but Trujillo obtained a site on the north bank just west of the junction of El Rito and the Chama, where he had resided before. During the ceremony, no commons was designated for grazing, a curious omission. In 1737, don Martín Elizacochea, the bishop of Durango, issued a license to the settlers for construction of a chapel during an episcopal visitation of New Mexico. Once completed, the chapel was dedicated to Santa Rosa de Lima, and the little village assumed the name of its patroness. Ruins of the structure are still visible on the Chama's south bank east of Abiquiú (SANM I: 954; Salazar 1976: 13-19).

A few months after the founding of Santa Rosa de Lima, several more settlers asked for farmlands in the Abiquiú area. Between January and April 1735, authorities in Santa Fe received petitions from six individuals and groups of families seeking small tracts of irrigable land near those granted to Bartolomé Trujillo and his friends. Because Governor Cruzat y Góngora had left the capital for an inspection of the El Paso region, responsibility for reviewing the requests fell to the lieutenant governor, General Juan Paéz Hurtado. Acting on his own authority, Paéz approved all the petitions from sixteen household heads for locations north and west of the sites granted in 1734 (SANM I: 320, 322, 518, 955, 1022, 1077). Local officials put the newcomers in possession during the spring, but their efforts to establish themselves on the land ended abruptly when the governor returned from El Paso. Angered by the actions of his subordinate, Cruzat y Góngora voided all the grants and demanded that the title documents be returned. He also decreed that the lands ceded had reverted to the public domain and that any houses erected must be demolished under penalty of a one hundred peso fine (SANM I: 524). Since the governor offered no explanation for his rulings, his motives remain shrouded in mystery. Additional settlement would have greatly increased Abiquiú's population and made a stronger barrier against attacks by hostile Indians.

Despite Cruzat's orders to vacate, it seems unlikely that all the settlers actually left the grants made by Paéz Hurtado. Some, like Manuel Bustos, obtained new grants within a few years; others, notably Gerónimo Martín, remained as squatters. Later records indicate that Martín and his large extended family continued to occupy his grant west of Abiquiú, which included the plazas of San José del Barranco and Los Silvestres (SANM I: 561). Although official policy discouraged frontier expansion for a few more years, the situation changed significantly following the arrival of a new executive, don Gaspar Domingo de Mendoza, early in 1739. During the next summer, Governor Mendoza approved two new grants at Abiquiú to Manuel Bustos and three members of the Valdés family, Rosalía, Ignacio, and Juan Lorenzo, who had previously attempted to settle near the headwaters of the Rio del Oso. Situated on the Chama's north bank west of Bartolomé Trujillo's rancho, the two grants became known as Plaza Blanca and Plaza Colorado in later years (SG 148, Plaza Blanca Grant; 149, Plaza Colorado Grant).

The two concessions did not go unchallenged, however. Soon after Mendoza had given approval, claimants to the Cristóbal Torres grant raised objections to the Valdés possession, which comprised part of the lands ceded in 1724. In their petition, the Torres heirs argued that, under Spanish law, damage suffered by a third party nullified a subsequent claim. While admitting that Cruzat y Góngora had restored the grant to the royal domain, the heirs asserted that the governor had later recognized their rights and made a verbal retraction. To avoid embarrassing himself, he allegedly suggested that a later incumbent could confer a new grant (SANM I: 1004). Evidently, Mendoza accepted their reasoning. On August 24, 1740, he revalidated the grant to Diego Torres and Juan José Lovato, a prominent citizen of the Rio Arriba region who served as alcalde mayor of Santa Cruz for many years. On September 11, the grantees received possession of the enormous grant from Alcalde Juan García de la Mora, who designated the old landmarks as boundaries. In later years, the property became known as the Juan José Lovato Grant, although the means by which Lovato secured a controlling interest is unknown. Subsequently, the new owner called his rancho "Santa Bárbara de Chama" and established headquarters on the vega near present Medenales (PLC 140, Juan José Lovato Grant). Surprisingly, the grant papers made no reference to Bartolomé Trujillo or the other heirs. Despite the oversight, Trujillo, the other grantees of 1734, and some of the claimants to the invalidated tracts of 1735 remained on the Lovato/Torres grant, oblivious to the change in ownership.

In May 1744, the Chama Valley received a brief visit from a distinguished member of the Franciscan order. Hoping to reinvigorate the missionary program in New Mexico, Fray Juan Miguel Menchero had traveled north from New Spain to inspect the far-off province and study conditions there. In a comprehensive report prepared for the viceroy, the Count of Fuenclara, Menchero included population figures compiled during his tour. At the lower end of the valley, in an area that he called "El Rancho de Chama y Rio del Oso," Fray Juan Miguel enumerated seventeen Spanish families; at Santa Rosa de Abiquiú he found twenty more. In contrast to these tiny communities, Menchero counted one hundred households at Santa Cruz de la Cañada, the administrative center of northern New Mexico (Hackett 1937, 3: 399). Because of their small population, the frontier settlements faced a continuing threat from belligerent Utes and Comanches, who bitterly opposed Spanish expansion of the Chama Valley. Although the two tribes had occasionally attacked Hispano villages in the early eighteenth century, during times of peace they also engaged in trade, exchanging hides, meat, and captives for horses and firearms. Although stringently regulated by Spanish authorities, commercial relations frequently caused hard feelings that led to combat, as the Indians sought revenge for unfair treatment. Hostilities escalated in the late 1740s, reaching a climax in August 1747, when Comanche warriors abducted twenty-three women and children during a massive attack at Abiquiú (John 1975: 243, 312-13; Hackett 1937, 3: 476-77). In October, Governor Joaquín Codallos y Rabal belatedly assembled five hundred soldiers, militiamen, and pueblo auxiliaries, who overtook the enemy, killing 107 Indians and capturing 206 Indians and 1,000 horses (Bancroft 1889 reprint 1962: 249).

Although Codallos seemed to have scored a notable victory, his triumph did nothing to restore morale on the northern frontier. Fearing renewed loss of lives and property, citizens of Abiquiú, Ojo Caliente, and Pueblo Quemado (today's Córdova) asked the governor for permission to abandon their settlements early in 1748. On March 30, Codallos reluctantly agreed to a temporary withdrawal (SANM I: 28). Eighteen months later, when conditions had not improved, panicky residents of Chama proposed a further retreat to Santa Fe or the Rio Abajo, but a new governor ordered the petitioners to stay on their lands. Fearing a general collapse in the north, tough-minded Tomás Vélez Cachupín imposed a stiff fine of two hundred pesos and four months in jail for those who tried to flee. To turn the tide and reinforce New Mexico's northern flank, Vélez commanded the timorous landowners from Abiquiú to reoccupy their ranchos in time for spring planting. As protection, the governor sent a small detachment of soldiers with the returnees and directed them to build adjoining houses around a defensive plaza. Any recalcitrants unwilling to go back would lose their lands (SANM I: 1100).

Not surprisingly, the decree aroused a storm of protest from the refugees. Several, including Bartolomé Trujillo, decided to give up their grants rather than return to Abiquiú. Members of the Valdés family, who had received lands north of the river in 1739, composed a long statement to Vélez Cachupín, explaining the many difficulties inherent in an immediate return. The governor stood firm, however, which caused the Valdés clan to reluctantly assemble their scanty possessions, gather a few livestock, and start back up the Chama. Other returnees included Manuel Bustos, Gerónimo Martín, and Miguel Martín, a captain of militia. Further support for the recolonization of Abiquiú came from thirteen families of genízaros (detribalized Indians living among the Spanish), forerunners of a larger group settled in the area by Vélez Cachupín in 1754 (SANM I: 1100). As conditions improved, other settlers slowly returned to their homes. In 1752, the governor conducted a census indicating that Abiquiú's Hispano population numbered seventy-three men, women and children grouped in eleven families. During the same year, Bartolomé Trujillo, one of the area's first settlers, paid a fine of sixty pesos for recertification of title to his rancho when Vélez suggested he might award it to someone else (SANM I: 976).

By that time, an uneasy peace had settled on the Chama Valley. Despite the settlers' fears, the danger of Indian attack at Abiquiú abated considerably in the 1750s. Using a judicious balance of threats and diplomacy, Vélez Cachupín maintained fairly good relations with both Comanches and Utes during his administration. He remained vigilant, however, recognizing the difficulty of persuading all *indios bárbaros* to give up war at the same time (John 1975: 323-29, 334). To bolster defenses at Abiquiú, he devised an unusual plan for establishment of a genízaro colony on the site of a prehistoric pueblo above the river. Following regulations found in the *Recopilación de Leyes de los Reynos de los Indios*, the magisterial Spanish legal code compiled in 1680, the governor allotted sufficient farmland, woods, and pasture for the genízaros to support themselves comfortably. Early in May 1754, near the end of his first term in office, Vélez rode up the Chama Valley to Abiquiú. Besides the usual soldiers and retainers, his followers included Juan José Lovato, alcalde mayor of Santa Cruz de la Cañada, and Fray Félix José Ordoñes y Machado, a Franciscan entrusted with spiritual supervision of the new colony. At the top of a small hill southwest of Santa Rosa, Vélez gave formal possession of the "Pueblo de Santo Tomás Apostol de Abiquiú" to Ordoñes as representative of his flock. With the formalities properly observed, Lovato began the serious business of designating boundaries for the lands, which became known as the Town of Abiquiú Grant (SG 140).

Because of the governor's careful planning, the reconstituted community seemed to promise a bright future for Hispanos and genízaros alike. In June 1760, when don Pedro Tamarón, bishop of Durango, made his famous visitation of New Mexico, high water prevented him from crossing the Rio Grande to inspect Abiquiú and Chama. Nevertheless, he reported that fifty-seven genízaro families, comprising 166 persons, resided at the new pueblo. According to the bishop, the Hispano population of Abiquiú had grown enormously since 1752: 104 households totaling 617 individuals (Adams 1954: 64). Before long, however, renewed warfare with nomadic Indian tribes caused the numbers to decline. At the end of his first term in 1754, Vélez Cachupín's well-crafted peace policy began to unravel; his successors simply lacked the political acumen needed to continue it. Fortunately, Vélez returned in 1762 for a second term in which he managed to stop the fighting through skillful diplomacy, but the respite ended five years later with the arrival of Pedro Fermín de Mendinueta, a new governor who remained in office for eleven years (John 1975: 329-32, 465-70).

Widespread violence swept over the Rio Arriba in the spring of 1768 following clashes with Comanches at Ojo Caliente and Taos. Several frontier villages, including Chama and Abiquiú, were deserted as before. When conditions improved slightly late in 1770, Mendinueta ordered the refugees to reoccupy their lands, just as Vélez had done two decades earlier. Like his predecessor, Mendinueta urged construction of defensive plazas enclosed by contiguous dwellings, noting that, in 1750, the settlers had left themselves vulnerable to attack by returning to their scattered ranchos (SANM I: 36). In spite of official pressure, it seems unlikely that any significant changes took place.

In 1776, valley residents greeted another high-ranking cleric, Fray Francisco Atanasio Domínguez, who was conducting an official visitation of New Mexico's missions for the Franciscan order. After his return to Mexico City, Domínguez wrote a detailed account of conditions he encountered that provides an intriguing picture of colonial life toward the end of the eighteenth century. As he rode north from Santa Clara Pueblo, he counted four Hispano settlements along the Chama's west bank. Extending for three leagues (approximately 7½ miles), they approximated the present villages of Guachapangue, El Guache, Hernández, El Duende, and Chili. Each placita had a name of its own, an arrangement that Fray Francisco described as "a whim," since all the communities blended together without any visible separation between them. According to the friar's calculations, the chain of settlement boasted a population of 340, presumably including Chamita on the east bank. Farms in the area raised "good crops of everything," thanks to ample water for irrigation (Adams and Chávez 1956: 119).

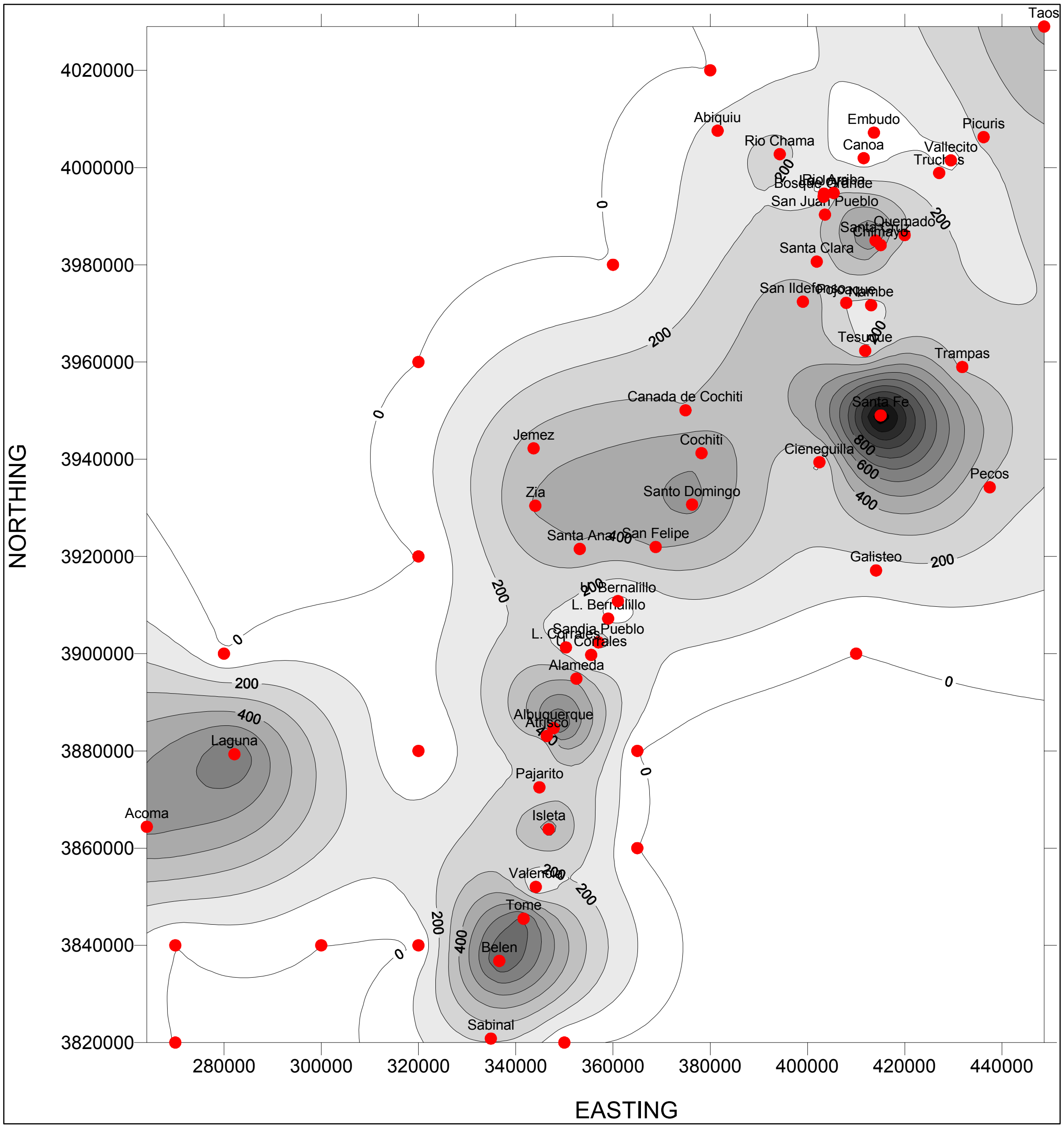


Figure O-1.3. Population Distributions in 1775.

Proceeding upriver over a rough road, Domínguez noted the Chama's dark red color that resulted from serious soil erosion. Eventually, he reached Abiquiú where he inspected the adjoining Hispano and genízaro communities. While resting at the pueblo, Domínguez admired the mission church, with its thick walls surmounted by a medium-sized bell hanging from an arch over the front door. As in most New Mexico churches, the interior was plain, but the building contained a choir loft in the rear, a noteworthy feature. Below the pueblo, Fray Francisco surveyed fertile fields and lush meadows bordered by groves of cottonwoods. Farmers from both ethnic groups irrigated from the river and from Abiquiú Creek, raising substantial crops in good years. Lacking experience, the genízaros lagged behind their Hispano neighbors in agricultural production. To supplement farm income, both groups eagerly engaged in Indian trade. Each year in October, the Utes came to Abiquiú for a fair in which they exchanged deer skins, dried buffalo meat, and captive children for knives, flour, and horses. Anxious to try out the trading stock, Indians and Hispanos organized impromptu horse races during the fairs, which caused great excitement. Abiquiú's citizens also enjoyed a yearly fiesta, which honored Santa Rosa, the community's original patron, instead of Santo Tomás, namesake of the pueblo (Adams and Chavez 1956: 120, 123, 125-26, 252-63).

In the years following the Domínguez visitation, Rio Arriba residents began to enjoy a period of relative stability, as Indian hostilities decreased significantly. In September 1779, Governor Juan Bautista de Anza, Mendinueta's successor, scored a great victory over the famous Comanche Chief Cuerno Verde during a campaign east of the Sangre de Cristo range near present Pueblo, Colorado. The defeat shocked the Comanche tribe, causing them to negotiate a treaty of peace at Pecos Pueblo early in 1786. Lasting many years, the agreement brought an unaccustomed calm to much of New Mexico (John 1975: 585-89, 670-76). A decade after Anza's triumph, a census enumerated more than eleven hundred people at Abiquiú residing in nine placitas between Medenales and Los Silvestres, just below the present Abiquiú Dam (N.M. Genealogical Society 1981: 111-24). Subsequent head counts showed continuing growth into the next century. Inevitably, population increases strained available land and water resources in the valley, causing emigration from Abiquiú to other locations, north and west, in the ensuing years.

After the Reconquest, settlement along the Rio Grande in White Rock Canyon was impeded by lack of arable land below San Ildefonso Pueblo. As livestock numbers increased, however, Hispano ranchers began to pasture sheep and cattle on the grasslands west of Santa Fe. In May 1742, Captain Nicolás Ortiz, a former commander of the villa's presidio, petitioned Governor Mendoza for a large tract of rangeland east of the Rio Grande. Known as the "Caja del Rio," the grant stretched south from the high mesa at the end of San Ildefonso's cultivation all the way to the escarpment at La Bajada. Well connected politically, Ortiz was the son of an important Mexico City family recruited by Vargas in 1693. As a teenager, he had been cited for bravery in combat with rebellious Indians during the Reconquest. Proudly declaring forty-nine years of military service, the captain requested land as compensation. The governor reacted favorably, but ordered Alcalde Antonio Ulibarrí to investigate possible adverse claims. Finding no opposition from neighbors at San Ildefonso and Jacona, Ulibarrí placed Ortiz in possession on June 18. Unexpectedly, the captain died soon thereafter, but his descendants retained the Caja del Rio for many years. As headquarters, they constructed a large hacienda with outbuildings and corrals in a broad valley called Cañada Ancha on the north side of the tract. In 1818, Navajo depredations forced the family to retreat to Santa Fe, but grazing operations continued on the grant's vast pastures whenever conditions were favorable (SG 63, Caja del Rio Grant).

In March 1742, Mendoza had approved another grant to Pedro Sánchez that was located across the river from the Ortiz grant and bounded on the north by San Ildefonso lands. Pleading extreme poverty, Sánchez hoped to obtain a tract big enough to support his huge extended family – a wife, twelve children, three orphaned nephews, and assorted retainers. Although Sánchez had made a poor choice, the easy-going governor agreed and ordered the Santa Cruz alcalde, Juan José Lovato, to handle the details. Once notified, pueblo officials did not object, but to prevent future disputes, Lovato erected a large cross that marked the grant's north boundary with San Ildefonso (SG 38, Ramón Vigil Grant). Sánchez's tenure was brief, however. No documentation is available, but he probably discovered that the grant could not sustain his many dependents. In 1750, Sánchez attempted to claim the rancho below Abiquiú first occupied by Bartolomé Trujillo. As we have seen, his request surprised Trujillo and caused him to regain the property by paying a substantial fine. After Sánchez left the Rio Grande, those lands were unoccupied for many years, but were eventually used for grazing by Anglo cattle ranchers.

When Sánchez requested his grant in 1742, he identified the south boundary as "the lands of Andrés Montoya." Sometime prior to 1740, Montoya had claimed a tract known as the Rito de Frijoles grant, located on the west bank between the river and the Valle Grande. To the south, the Cañada de Cochití marked the property line. The grant included much of Frijoles Canyon, where the headquarters of Bandelier National Monument is today. Like many other grantees, Montoya was a veteran of several Indian campaigns and had later served as alcalde of the three eastern Keres pueblos: Cochití, Santo Domingo, and San Felipe. Evidently, the family maintained continuous occupation for two or three generations, irrigating small plots of farmland from Frijoles Creek. In 1780, a younger Andrés Montoya asked Governor Anza to transfer ownership of the grant to Montoya's son-in-law, Juan Antonio Luján, who had been residing there. Subsequently, title passed to Luján's daughter, Antonia Rosa Luján, and her husband, José Antonio Salas. The Navajo raids of 1814 forced the couple to evacuate and move closer to Cochití, but their descendants continued to farm in the canyon whenever possible (SG 133, Rito de los Frijoles Grant).

Below the Frijoles grant at the end of White Rock Canyon, the valley widens somewhat, allowing agriculture to become more practicable. As a result, settlement occurred earlier in this area than in the constricted canyon above. In 1728, Governor Bustamante received the usual petition from Antonio Lucero announcing his desire to settle lands on Cochití mesa where Indians from the pueblo had retreated during the rebellion. Including ten fanegas of wheat land and two more for maize, the tract also provided ample pasture in the western mountains for saddle horses and flocks of sheep. Since the governor made no objection, Lucero received possession of the grant on August 8 from the alcalde of the Keres pueblos, Captain Andrés Montoya (SG 135, Cañada de Cochití Grant). Although originally awarded to Lucero alone, the grant developed into a community enterprise with many families in residence. In June 1760, when Bishop Tamarón toured New Mexico, he found forty Hispano households comprising 140 persons west of the river in the Cañada settlement (Adams 1954: 65). Sixteen years later, Father Domínguez reported that the Spanish population had increased to 307 persons, who lived in scattered ranchos along a small stream. Farmlands were of good quality, he wrote, but crops were scanty because irrigation water usually dried up when needed most, leading to severe hardships for the settlers (Adams and Chávez 1976: 159). Domínguez may have exaggerated the problem somewhat, since Cañada de Cochití continued to be a viable community, in spite of continuing water shortages, until its abandonment early in the twentieth century.

To summarize, settling New Mexico's northern frontier proved to be a long and difficult process. Don Juan de Oñate established his first headquarters near the jurisdiction of the Rio Grande and the Rio Chama, but the colonists deserted that site in 1610 after his successor relocated the provincial capital to Santa Fe. Subsequently, a few pioneers began to cultivate small tracts of irrigable land at La Cañada, a valley extending east from the Rio Grande. Their farms were abandoned in 1680, however, when the Pueblo Indians rose in revolt, forcing the settlers to join the general retreat to the south. After twelve years at El Paso, Spanish rule was reestablished in New Mexico by Governor Diego de Vargas, a tough and resourceful leader. To protect the colony's northern frontier from incursions by nomadic Indian tribes, Vargas founded La Villa Nueva de Santa Cruz de la Cañada in 1695. Originally settled by newcomers from Mexico City, Santa Cruz became the jumping off place for families hoping to locate farmlands to the west in the Chama Valley.

Early in the eighteenth century, veterans of the Reconquest who hoped to find new homes along the Chama were hindered by conflicting land titles. Overlapping grants resulted in extensive litigation to resolve boundary disputes. During the administration of Juan Domingo de Bustamante, however, the governor mandated a compromise that facilitated establishment of a series of small placitas stretching upstream from Corral de Piedra near present Española as far as Rio del Oso. To further promote agricultural expansion, Bustamante also authorized the Cañada de Cochití Grant below Santa Fe on the Rio Grande's west bank.

During the 1730s, settlement on the Rio Chama advanced to Abiquiú, but Spanish intrusion into ancestral hunting grounds provoked violent opposition from Ute and Comanche war parties. Fearing for their lives, the settlers fled from Abiquiú in 1748, although most of them returned within a few years, on orders from Governor Tomás Vélez Cachupín. For some years, the Rio Arriba region enjoyed relative peace, thanks to the governor's adroit Indian policy. Conflict resumed in the 1760s and 1770s, but the Comanche threat ended after the decisive defeat of Cuerno Verde's warriors in 1779. as hostilities wound down at the end of the eighteenth century, the Rio Arriba experienced a remarkable increase in population. Like previous generations of New Mexicans, vecinos (citizens) of Abiquiú and neighboring villages began to search for vacant lands with water sources to sustain their families. As they developed new grants to the north and west at Piedra Lumbre, Cañon del Rio Chama, and Tierra Amarilla, the settlers sustained and nurtured the same traditional culture that first came to New Mexico with followers of Oñate and Vargas.

Conditions were not radically different at the time of Tamarón's (1760), Dominguez's (1775), or Morfí's (1782) visitations of New Mexico. Dominguez' census, summarized in **Figure O-1.4**, shows that settlements continued to be restricted to the mainstem of the Rio Grande. This assessment is confirmed by Morfí's narrative (Thomas 1932:87-120). Moreover, there is little evidence that new settlements had been established in outlying portions of the Spanish realm in New Mexico.

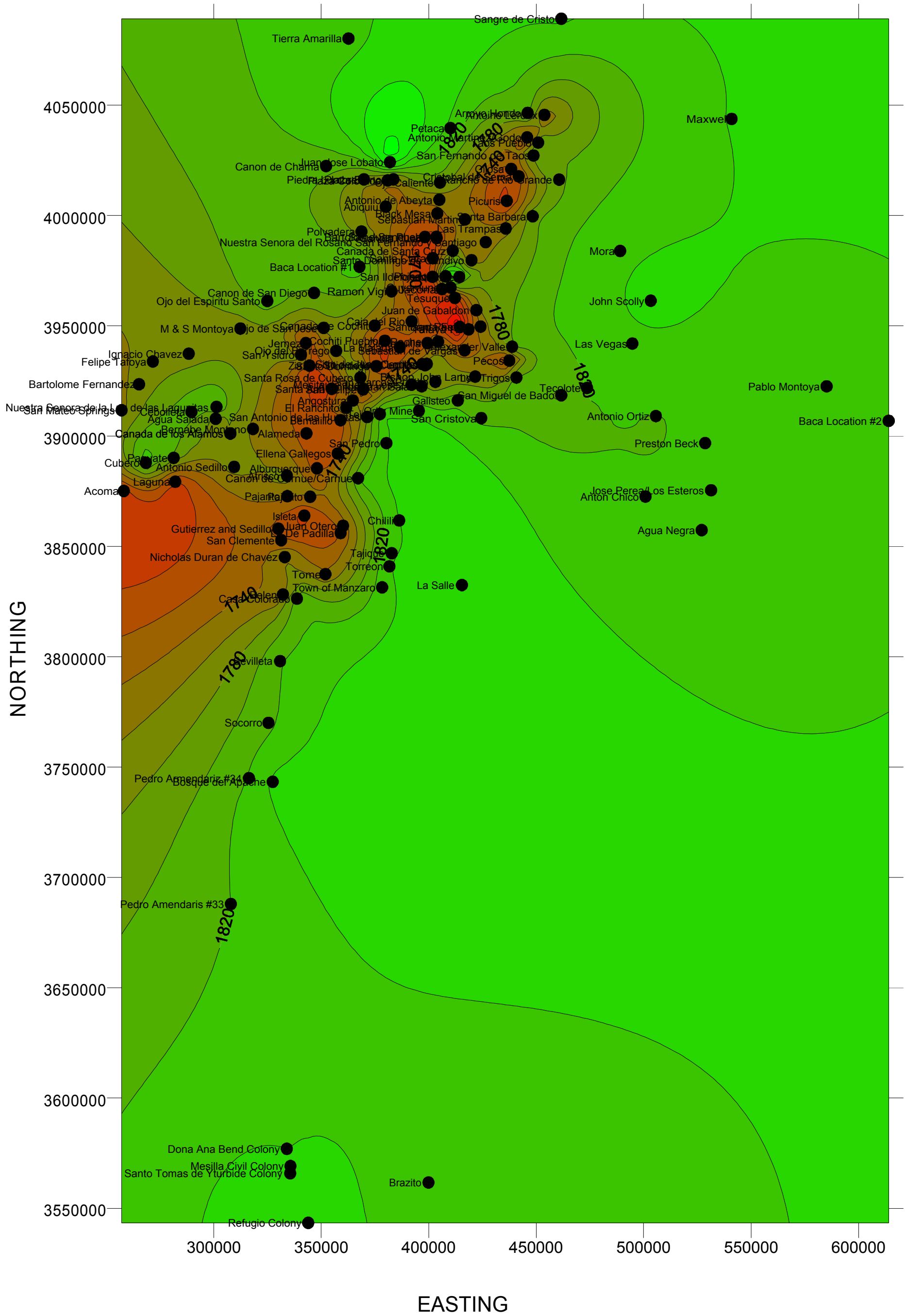
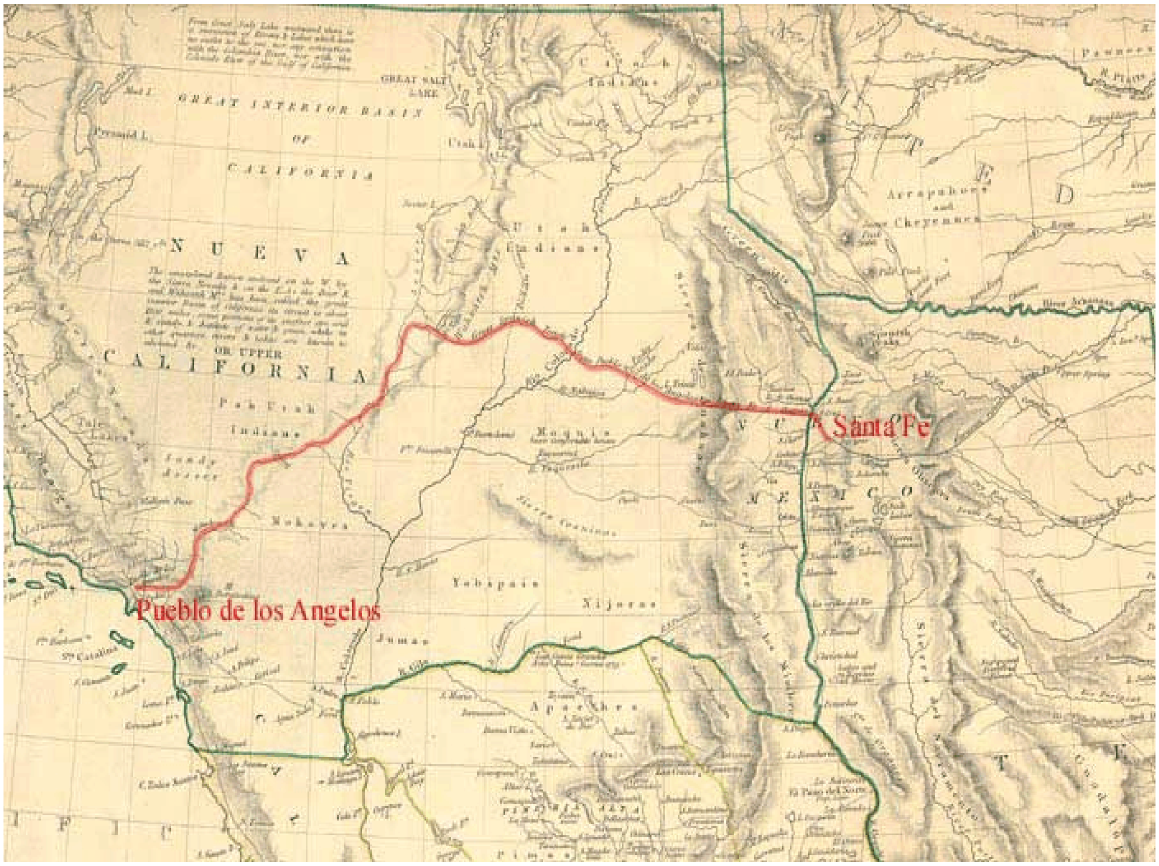


Figure O-1.4. Time-sequent Establishment of Spanish and Mexican Land Grants.

The general pace of land grant awards abated prior to Independence (1821), although some grants were made during this period (Williams 1986:105). Along the Rio Grande, early nineteenth century land grants included Galisteo (1814), Arroyo Hondo (1815), Socorro (1815), and Cañon de Carnué (1819). It was also during the eighteenth century that the Old Spanish Trail was established (Crampton and Madsen 1994). This southern branch of this trade route, first traversed by Rivera in 1765, almost certainly followed earlier Native American trading paths (Wendorf 1953:7). In 1776, the southern route was more firmly defined by the Domínguez-Escalante expedition (Chavez 1995; Wendorf 1955:7-8). Beginning at

Abiquiu, and extending northwest up the Rio Chama, the trail diverged into the headwaters of the San Juan River and then passed into southern Colorado and Utah (**Figure O-1.5**). By the beginning of the nineteenth century, the Spanish Trail had become one of the major trading routes connecting New Mexico with Spanish settlements in Arizona and California and Abiquiu became the primary point of departure for trading caravans heading west to California (Swadesh 1974:61, 63).



Source: Old Spanish Trail Association 2002

Figure O-1.5. Alignment of the Old Spanish Trail.

Through much of the Spanish Colonial Period, hostilities, epidemics, and other factors all served to limit the expansion of Spanish settlements in the region. This was due, at least in part, to substantial decreases in the size of puebloan populations and attendant impacts to the *encomienda* system on which Spanish settlement was based. By 1803, toward the close of the Spanish Colonial Period, the region was described by Chacón as having about 35,700 people (Simmons 1985:84). In the absence of readily accessible markets, its agricultural economy operated at subsistence-levels of production (Simmons 1985:84; Reeve 1961:1). Sheep herding, described above, was a notable exception, with Chacón indicating that 25,000-26,000 sheep were driven annually to presidios in northern Mexico (Simmons 1985:85). Yet, importation of manufactured goods—notably horses, mules, linen goods and cotton textiles—underscored the fragility of the region's economy.

Spanish settlement brought new technologies and ways of life to indigenous peoples. Among the most important introductions was the use of metal, the introduction of domestic animals and, to the detriment of the region's inhabitants, Old World diseases (Bartlett 2002:13, 77-80; Weber 1992:303-304). While the colonists entered the region with the notion that they would reconstruct Spanish society in these new lands, in the end it was the settlers who were reconstructed by their pueblo neighbors. Very little of Spanish society was evident in the character of the region toward the end of the Spanish Colonial Period.

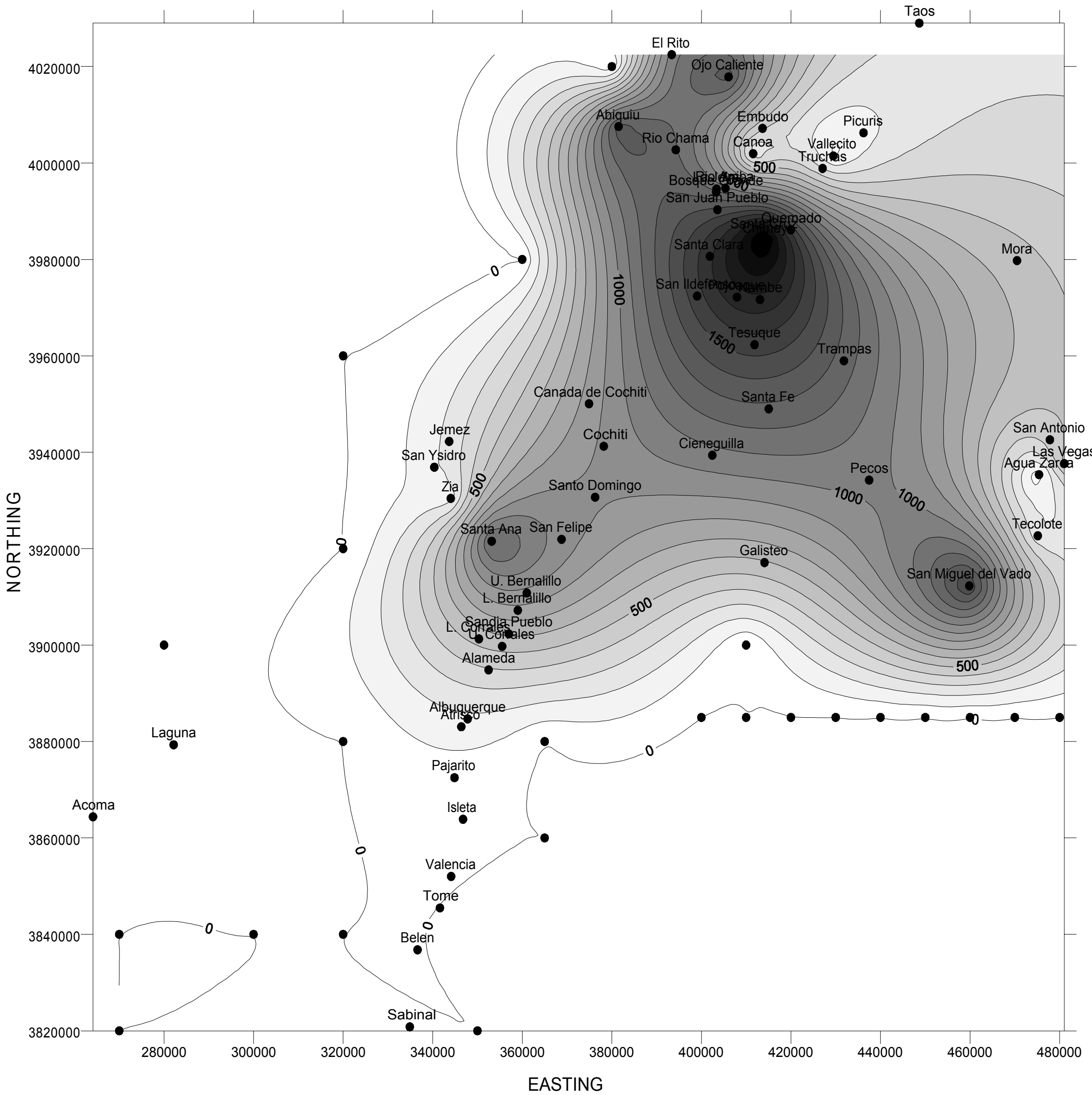
1.3.1.2 Mexican Period (A.D. 1821-1848)

Mexico's declaration of independence from Spain in 1821 was accompanied by the opening of the Santa Fe Trail. Yet, the change in administration had little or no effect on governmental policies nor on the lives of most residents of New Mexico during this period (Carlson 1990:13).

There were additional Mexican land grants awarded during this period including the Cañones del Riaño (1823), Vallecitos (1824), Petaca (1824), Tecolote (1824), Tierra Amarilla (1832), Baca Location #1 (1835), Chilili (1841), Sangre de Cristo (1843), Vigil and St. Vrain (1843), Cebolla (1845), and Bosque del Apache (1845) grants (Brayer 1949:60, 128, 156, ; Swadesh 1974:54-55, Williams 1986:105) . Other settlements, notably Mora, located to the east of Santa Fe were also established in the early nineteenth century (Chávez 1955:319-320).

The Mexican Period saw progressively greater interaction between Euro-Anglos from America and New Mexico's Native American and Hispanic residents. In recognition of increased trade with Americans from the east, Taos was made an official port of trade in 1837, while Socorro, New Mexico, remained on the edge of the Mexican frontier (Bloom 1913:13; Carlson 1990:75-78). The area between Socorro and El Paso continued, as it had during the preceding 200 years, to be devoid of Mexican occupations during this period (Bloom 1913:13).

In 1822, at the beginning of the Mexican Period, New Mexico's population totaled about 40,000 people, including both Mexicans and Indians (Bloom 1913:29). According to Narvon's 1827 census, New Mexico's population had increased to 42,217 people. Toward the end of the Mexican Period, in 1840, Manuel Armijo's reported population census indicates that 55,403 people were in the region. This roughly translates into a 2.1 percent annual population growth rate during the period between 1827 and 1840. The distribution of the population in 1845 is shown on **Figure O-1.6**.



(Note that no census of the pueblos was taken at this time)

Figure O-1.6. Population Distributions in 1845

The 1845 census, which does not include censuses of pueblos, is incomplete (Olmstead 1975). However, it does illustrate that Mexican settlements, consistent with the “budding” process described elsewhere, had spread eastward during the preceding few decades. The towns of Vado, Anton Chico, Tecolote, Las Vegas and others located northeast of Santa Fe all exhibit substantial population growth during this interval. In general, then, settlements were pushed eastward into the northeastern quarter of New Mexico. In the northwestern quarter, with the notable exceptions of settlements at El Rito and Ojo Caliente, Mexican settlements remained few in number due largely to on-going conflicts with the Navajo.

As was true during the Spanish Colonial Period, sheep raising remained one of the most important economic activities during the Mexican Period. According to Navrona’s 1827 census, approximately 247,000 sheep were managed by herders at the beginning of the Mexican Period (Bloom 1913:18, 40; Carroll and Haggard 1942: Report Number 1). Of these, 65 percent of the sheep were concentrated in the

Albuquerque *alcaldia*, while the remainder were divided between the Santa Fe (26 percent) and the La Cañada de Santa Cruz *alcaldias* (10 percent). The wool produced in these regions was cleaned and spun into a variety of textiles used both locally and as integral components of long-distance trade with California and northern New Mexico. Given the scarcity of horses and mules in New Mexico, which numbered only 2700 animals in 1827, New Mexico textiles and sheep-on-the-hoof were traded for horses and mules from California, so that sheep continued as a crucial component in the economy of the region during this period (Carlson 1990:79; Reeve 1961:13).

Trading across the Old Spanish Trail, discussed above, intensified during the Mexican Period and included both Mexican and Anglo traders (Swadesh 1974:60-61). Many of the alternate routes along the trail which shortened its distance were identified and used by traders traveling to California. According to the Frenchman, Duflot de Mofras (Utah Bureau of Land Management 2002)

> Caravans traveled once a year from New Mexico to Los Angeles. These consist of 200 men on horseback, accompanied by mules laden with fabrics and large woolen covers called serapes, jerzas, and cobertones, with are valued at 3 to 5 piasters each. This merchandise is exchanged for horses and mules on a basis, usually of two blankets for one animal. Caravans leave Santa Fe, New Mexico, in October, before the snows set in...and finally reach the outlying ranchos of California from where the trail leads into El Pueblo de los Angeles. This trip consumes two and one-half months. Returning caravans leave California in April in order to cross the rivers before the snow melts, taking with them about 2,000 horses.

By 1844, the Mexican government had suspended its annual gifts to many Indian groups. In the Rio Chama Basin, the Utes responded by inaugurating persistent raids against frontier towns, particularly Abiquiu and Tierra Amarilla (Swadesh 1974:62). Although temporary summer sheep camps seem to have continued throughout this period, the region was nonetheless subject to hostilities well into the Euro-Anglo Period. Despite hostilities, and the expansion of trade during the Mexican Period, settlements and associated populations remained largely restricted to the Rio Grande valley and its major tributaries.

1.3.1.3 Euro-Anglo Period (1848 - present)

Initial perceptions by Anglo-Americans upon their arrival in New Mexico were far from complimentary (Bloom 1959). One observer commented (Carlson 1990:57):

> The population of New Mexico hitherto has not, unfortunately, been of the progressive kind. The Spanish and Mexican race, of whom until recently ten tenths, and at this time nine tenths of the population is composed, has caused the country to progress scarcely a move in the march of material improvement and wealth beyond what it was in the days of the Spanish vice-royalty in Mexico to which it was once subject.

The chaos that seemed to characterize the newly-acquired territory grew even worse with the outbreak of the Civil War. Between 1861 and 1862, Confederate forces seized a series of Union posts beginning in El Paso, Texas, and extending northward up the Rio Grande toward Santa Fe. Only after the Confederates were defeated at the Battle of Glorieta Pass in the spring of 1862 did any semblance of order return to the territory. By 1865, the Santa Fe-Durango stage route extending from Santa Fe northwestward through San Ysidro, Cuba, Haynes Station, Truby Stop, and Largo to Aztec had been established in an effort to improve communications and travel in the northern reaches of New Mexico (Williams 1986:18). This stage line was to remain in operation until 1881.

Much of the impetus for Anglo settlement in the project area can be traced to passage in 1862 of the Homestead Act. Intended to promote settlement of the American West, the Act provided 160 acres (later, 320 acres) to claimants once they "proved up" their claim by living and working on it for five years (Carlson 1990:53-54). Anglo settlements in the project area did not emerge until the late 1870s. In the Rio Puerco, settlements that had been abandoned in 1774 were finally reestablished (Widdison 1958:56). Unless otherwise noted, all the following establishment dates are from Julyan (1996). Among the earlier settlements in the project area were Blanco (1870s), Lumberton (1881), Dulce (1883), Cuba (1887), Cedar Hill (1887), Rosa (1888), San Luis (1890), and Sheep Springs (1892). Others such as Fairpoint (1894-1898), Pendleton (1903-22), Liberty (1907-1920), Haynes (1908-1929), and Gobernador (1916-1942) were established only to be abandoned within a few years or decades (Williams 1986:147).

Many initial economic activities typical of the mid-late nineteenth century focused on farming and ranching. Farming varied from rainfall-based dryland farming in upland areas to irrigated agriculture in river valleys that had relatively permanent flows. The establishments of the settlements listed above were almost invariably accompanied by the immediate construction of irrigation ditches (Ackerly 2002).

Ranching continued to focus largely on sheep, although cattle soon began to appear and eventually equaled sheep in importance. As in the Mexican Period, sheep continued to be an important aspect of Albuquerque's economy throughout the nineteenth century. Sheep ranching during the Euro-Anglo Period expanded north and east to Rio Arriba, Taos, and San Miguel counties, as well as into parts of Valencia County south of Albuquerque (Carlson 1969:33). Sheep continued to play a critical role in the region's economy due to increased demand for fresh meat as a consequence of, first, the 1849 California Gold Rush and, later, the need for meat and wool sparked by the outbreak of the Civil War and an attendant increase in the price of woolen garments (Carlson 1969:31-35). By 1880, sheep numbered 2,000,000, up more than eight-fold from the earlier 1827 estimate of 250,000 (Carlson 1969:33).

Beginning in the 1850s and persisting through the 1860s, there were trail drives of large sheep herds westward along a route that closely paralleled the Old Spanish Trail (Williams 1986:121). Trail drives eventually extended north into Wyoming, east toward Kansas, and west to California (Carlson 1969:34-35). Española, in the heart of the Rio Chama country, became the headquarters of Frank Bond's sheep operation, one of the largest in the territory (Carlson 1969:37). By the early twentieth century, there were 1.8 million head of sheep on the Navajo Reservation, comprising almost 93 percent of all livestock on the reservation (Acrey 1994:157).

The rapid pace of settlement, accompanied by expansion of both farming and ranching, led to the construction of the "Chili Line" of the Denver & Rio Grande Western Railroad in 1879 and, in 1881, the "Farmington Branch" (Whitten and Powers 1980:25). Intended largely to transport commodities—particularly fruit—northward and manufactured goods into the San Juan Basin, a spur line extending from Durango, Colorado, southward to Aztec and Farmington was completed in 1905 (Myrick 1990:130).

During this same period, a series of mineral discoveries, particularly in the San Juan basin, caused the boundaries of some Indian reservations to be redrawn so that mining operations might be established. In 1872, under the terms of the Brunot Agreement, the Utes lost a substantial portion of their original reservation (Swadesh 1974:97). Concomitant with the opening of these new lands for mining was an influx of largely Hispanic settlers into the upper reaches of the Rio Chama and west into the San Juan basin (Swadesh 1974:97-100). Many of the earliest settlers originated from the Abiquiu and lower Rio Chama Valley (Swadesh 1974:105).

In Navajo county, the late nineteenth century and early twentieth century were characterized by the establishment of numerous trading posts. Beginning in 1869, trading posts associated with army garrisons at Ft. Defiance and Ft. Wingate were opened for Navajo trade (Acrey 1994:132). In the mid-1880s, a trading post was opened in Fruitland (Acrey 1994:132), soon followed by trading posts at Crystal (1892) and Two Gray Hills (1897). Trading posts provided both an outlet for goods, notably blankets and jewelry, produced by Navajo craftspeople, as well a source for manufactured Anglo goods.

1.3.2 The Southern Area (Reaches 13 through 17)

To the south, in the area between the Rio Puerco and El Paso, the early history is somewhat different than that observed in the northern reaches of the planning area. Spanish and Mexican Period occupations are virtually absent, while the majority of archaeological remains are associated with the Euro-Anglo Period.

1.3.2.1 The Spanish Period (1540-1821)

At the time of Spanish contact, the southern project area contained numerous pueblos. Along the mainstem of the Rio Grande, named pueblos appearing in Spanish chronicles included Sevilleta, Pueblo de Arena, Almillo, El Barro, Pueblito Point, Pilabo/Socorro, Teypama, Plaza Montoya, Qualacu, Nuestra Señora, San Pascual, Tiffany, Senecú, Magdalena, and Bear Mountain (Bartlett 2002:55). By the mid-1600s, coincident with decreases in the numbers of occupied pueblos in the northern reach of the project area, the number of southern pueblos—those located from Socorro south—decreased from 14 to three (Bartlett 2002:62). This confirms the rather pan-regional abandonment of contact period pueblos across much of New Mexico.

Largely by-passed by the Spanish in their rush to colonize the northern reaches of the Rio Grande, the southern part of the project area remained largely devoid of Euro-Anglo residents until the mid-nineteenth century. Even as late as the nineteenth century, the region between El Paso, Texas, and Socorro, New Mexico, was referred to as *la tierra afuera* (the land outside) (Bloom 1913:12). Archaeological investigations have located pre-Revolt Piro pueblos at Sevilleta (*ca.* 1620-1670), Socorro (1626-1680), Qualacú (*ca.* 1598-1692), San Pascual (*ca.* Pre-1681), and Senecú (*ca.* 1581-1680); most appear to date between 1581 and 1680 (Marshall and Walt 1984:246-257).

Indigenous peoples at the Paso del Norte included the Mansas (*Manso*, lit. peaceable). Described in detail by Benavides (Ayer 1965:13-14), the Mansos lived in brush huts, relying primarily on wild plant and animal resources obtained from the Rio Grande and surrounding uplands; fish and mice specifically mentioned by Benavides (Ayer 1965:14; Bandelier and Hewett 1978:140).

El Paso was to play an important role following the Pueblo Revolt of 1680, inasmuch as Spanish and Native Americans fleeing the devastation in the north eventually took refuge at its presidio (Weber 1992:137). The arrival of displaced Native Americans loyal to Spain led to the founding of the village of Ysleta del Sur, one of the southernmost pueblos in the planning area. With the 1680 flight of the Spanish and their Indian allies from northern New Mexico to the Paso del Norte region, the pressure on local agricultural production systems to sustain such an increase in people appears to have contributed to the expansion of irrigation throughout the valley, a trend that continued in succeeding years. Within a decade, El Paso became the staging area for Vargas' eventual military expedition to recapture northern New Mexico in 1692.

White (1950:7) notes that there is no documentary evidence indicating that irrigation agriculture was practiced to any great extent in the El Paso region between 1581and 1650. The earliest record of American Indian irrigation agriculture in El Paso appears in Bolton (1930:178). Referring specifically to the Pueblo of Senecú in 1582, Espejo noted that: "They [the Piro] have fields of maize, beans, gourds and piciete, in large quantities, which they cultivate like the Mexicans. Some of the fields are under irrigation, possessing very good diverting ditches, while others are dependent on the weather [rainfall]."

In 1659, following the founding of the mission of Nuestra Senora de Guadalupe de Paso del Rio, Hackett (1942: 193-213) notes that: "Father Garcia was there attending to the establishment of a farm, and obliging even the heathen to construct a ditch for it, with great labor, from the Rio del Norte [Rio Grande]." This account places early irrigation systems on the southern or right bank of the Rio Grande in the vicinity of the modern city of Juarez, Mexico. Whether there were irrigation systems on the northern or left bank of the Rio Grande remains unclear. White's (1950:9-10) review of documentary sources suggests that irrigation systems were not present in the area of modern-day El Paso, Texas, prior to about 1680.

However, irrigation agriculture did not come to the fore until after the Pueblo Revolt of 1680. With the removal of Spanish-Americans from northern New Mexico to the Paso del Norte region, the pressure on local agricultural production systems to sustain such an increase in people appears to have contributed to the expansion of irrigation throughout the valley. Aid to Otermin's refugees was decreed to include 150 plowshares, 600 large hoes, 24 pickaxes, and 24 iron shovels (White 1950:12).

Sometime between 1681 and 1683, additional irrigation canals appear to have been constructed by Otermin (White 1950: 14). In 1683, Otermin's successor, Cruzate, tried to induce Spanish settlers in the vicinity of San Lorenzo, on the Juarez side, to relocate near Nuestra Senora del Guadalupe. His inducement, in part, would allow the settlers to make use of an existing irrigation canal and an offer to widen the canal (White 1950:15). Two years later, in 1685, a drought period that coincided with the Manso revolt in the El Paso area, was noted to have led to widespread crop failure in the El Paso area (Castañeda 1936:267).

By 1726, de Rivera noted that the region contained a number of irrigation ditches diverting water from the Rio Grande (White 1950: 18). Casteñada (1936: 276) relates that Rivera found:

> In this same direction [east of El Paso] there is a spacious valley dotted with farms where they plant wheat, corn, beans, and all kinds of vegetables, as well as a quantity of vineyards which yield fruit of a superior quality to that of Parras. The natural fertility of the land is improved by the number of irrigation ditches which carry water from the said Rio del Norte, making the farms independent of drouth.

Retrospective accounts of conditions in 1744 are presented in Morfí's description of the El Paso region. On the left (northern) bank of the Rio Grande, Morfí recounted that (Thomas 1932: 110):

> In the neighborhood of El Paso there are various haciendas and ranches because of the possibilities which the Rio Grande and other different arroyos and springs offered. Don Alonzo Vitares Rubin de Celis, Captain of the Royal Presidio of El Paso, founded the hacienda of cultivated fields, called La Rancheria at a distance of seven leagues from El Paso, which in 1744 had for the tilling of lands and raising of herds twenty families of Spaniards and some Indians.

In 1760, following a visit to the El Paso region, Bishop Tamarón reported that the irrigation canal diverted approximately half of the flow of the Rio Grande and that there were many smaller canals that distributed water to fields in the region (White 1950: 18). According to Tamarón, there were 2479 Spaniards and 249 Indians at the presidio in 1760 (Adams 1953:193).

El Paso continued to be a center for agricultural production throughout the eighteenth and nineteenth centuries. Agriculture in the El Paso region, as in northern New Mexico, depended on the construction and maintenance of irrigation systems. According to White (1950:4-7), the earliest documentary evidence of irrigation agriculture in the valley appears sometime between 1659 and 1661. Two years later, in 1782, Fray Morfí noted that the mission of Nuestra Senora de Guadalupe had expanded dramatically. Morfí attributed the expansion of Spanish settlements in the El Paso region directly to the irrigation systems then present in the valley (Thomas 1932: 109):

> Some families of Spaniards have been added to them and because of the facilities of irrigation, the village pushed down to the river so that today the place occupies two leagues of maize, beans, and vegetables, especially grapes, which the owners pick and having made wine, sell profitably in Chiguagua [Chihuahua] and Sonora.

In 1773, a long-time resident described the El Paso region as follows (Hackett 1942: 507-508):

> In these places [Nuestra Senora de Guadalupe] Indians and Spaniards live commingled, the former having their farms and a branch of irrigating ditch, while the latter have the main ditch, containing two floodgates from which the Indians' water comes. The upkeep of the dam is obligatory upon all. It is made of wattles, as the terrain of that river does not permit any other kind of fabrication, to say nothing of the trouble caused by its excessive floods and freshets, for it not seldom happened that after a dam had been built of stones, fagots, and stakes, it was necessary to tear it down in order to prevent inundation of the town. This causes constant labor for the inhabitants, as does also the cleaning of the ditch, which caves in frequently, because of the weakness of the fine sandy soil. The lands are extremely fertile, not altogether because of the quality of the soil, which is thin, but because of the benefit furnished by the water in bringing with it a thick mud which serves as manure for the land, leaving on top of the irrigated earth a glutinous scum which resembles lard. The products yielded by this land are: Excellent wheat, free of all darnel, and with a remarkably large grain; good maize, when they know how to work the soil, which supports it only by making the furrows deep, for, on account of its lightness, if the corn is not well rooted the strong winds (to which this country is subject) uproot it and lay it flat on the ground. The land also produces beans of two sorts, black and spotted, of the size of Indias; white and black broad beans; fair-sized chick peas, though not very large; anise, and all kinds of vegetables and garden-stuff of very good quality, especially large sweet onions. There are many vineyards of excellent wild grape stock, but the vine is slender, and for this reason it is necessary for its preservation to cover it. The grape, which has a good taste, is black, and there are some vines of muscatel. There are many fruit trees, which yield largely if they are not attacked by frost at a critical time. The principal ones, of which there is an abundance, with large trees and fruit, are bergamot pears and apricots; of a more moderate size, though not less abundant in fruit, are the apples and peaches. All yield so bountifully in a good year that no one takes care of or guards them; the most industrious dry the fruit in the sun to preserve it, and not seldom it serves as food for the poor. Most of this land lies in the valley of the river, facing a broad inlet formed by its banks, and only the church and the royal buildings are situated on the height at the margin of the said river bed.

Further downstream, in the vicinity of San Lorenzo/Senecú on the Mexican side and opposite the modern town of Socorro, Texas, the same resident provides a general described the valley and its agriculture as follows (Hackett 1942: 507-508):

> They [Sumas] have a ditch apart from the bed of the river with which they water their lands and those of some white citizens who live at the mission in order to prevent dissensions (sic). This land has the advantages spoken of above, but is not so productive because there has not been time to clear and plant it, as all of it requires. In the same direction follows the mission of La Isleta [Ysleta], abundant in everything, with its separate irrigation ditch and a large number of laborious, civilized, and industrious Indians. Then follows in the same direction, the mission of Socorro, which has a small number of Indians, on account of being made up of natives from other

> countries. They are the ones who were brought from the Indians of New Mexico, and by them from the Comanches, who are at war with the Apaches. With them are quite a number of white people who work good land, much of which was accidentally given to them by the river when it changed its course to the opposite bank. They guard against the danger that the river may return to its old course by making deep ditches through which it may flow in such an event. There are a few cattle and sheep in the country, but the river abounds in fish, known as rock fish, although some call it bream. Other delicious kinds are the corazon and the *enguila*, all of more than medium size. The *enguilas* are found more often in the ponds formed by the overflow of the river than in its channel.

What emerges from this very detailed description of the El Paso region in the late 1700s is a picture of a mosaic crop production strategy with a primary emphasis on wheat and corn. At the same time, not all portions of the El Paso valley were equally subjugated and the overall productivity of the valley varied considerably from one place to another. Irrigation facilities appear to have consisted of three spatially-distinct systems, each with its own diversion point and associated dam. The approximate locations of these systems were at the narrows near the modern-day American dam, at Senecú, and at Ysleta. All of the systems appear to have diverted water from the right (south) bank of the Rio Grande. At the same time, the overall character of the floodplain of the Rio Grande appears to have consisted of heavy bosque interspersed with oxbow lakes reflecting the presence of former river channels.

At the end of the eighteenth century, Spanish explorers found myriad small groups of hunter-gatherers situated along the margins of the Rio Grande River, including Sumas, Jumanos or Quemanderos and, finally, Apaches (Forbes 1957). These groups lacked large agricultural villages that were the foundation of Spanish colonization policies which required access to native land and labor. Therefore, these groups were largely ignored and standard Spanish *encomienda* practices were largely abandoned. Because of Spanish disinterest, there is a corresponding dearth of documentary information about Native Americans in southern New Mexico throughout most of the Spanish Period.

The Suma groups thought to have occupied western Chihuahua as far north as El Paso disappear from narrative accounts between 1680 and 1710, although it is not certain whether their absence fromdocuments signals their disappearance as ethnic groups. They may well have been absorbed into the Chiricahua Apaches of southeastern Arizona (Forbes 1957:321) inasmuch as intermarriage between groups is thought to have been common (Forbes 1957:326). There is also evidence to suggest that Sumas were confounded with adjacent Manso groups (Forbes 1957:328). Sumas in the El Paso area remain prominent in documents as a thorn in the side of Spanish authorities well into the 1700s (Forbes 1957:332), but were so decimated by smallpox that, by 1762, their population was sent to join Lipan groups at San Lorenzo (Opler 1974:341).

Manso Apache groups occupied the Jornada del Muerto between El Paso and Las Cruces no later than 1630. By 1659, Manso groups already residing in the El Paso area had been consolidated at Nuestra Señora de Guadalupe de los Mansos (Opler 1974:343). By 1683, a second rancheria containing Mansos is noted at the church of San Francisco de los Mansos situated within 8 to 9 leagues from El Paso.

Not all Manso elements remained at the mission. Documents suggest that the Spanish drew a distinction between "civilized" and non-reservation Manso elements (Forbes 1957:325-326; Opler 1974:344). This is especially true following the Pueblo Revolt in 1680 and the subsequent withdrawal of Spanish forces to the El Paso area. By 1796, all of the native tribes in the area were referred to as Apaches, although numerous regional subgroups were recognized (Matson and Schroeder 1957:337).

While uncertainty remains, it is thought by some that Mescalero Apachean elements were situated in the project area by the late 1690s and certainly no later than the 1780s (Ray 1974:179; Opler 1974:349). Like the Mansos, the Mescaleros were mobile hunter-gatherers. Consistent with this adaptive pattern, population densities appear to have been quite low. Population estimates from 1847 suggest that no more than 1,500 Mescaleros were in the region north of El Paso (Ray 1974:182, 207). In this region they remained largely undisturbed until the arrival of Anglos in the 1850s. By 1862, systematic military campaigns were launched by the Army against the Mescalero culminating in their reduction to the Bosque Redondo and Ft. Stanton reservations.

Archaeological studies of sites associated with the activities of such Native Americans in the southern project area is lacking. Matson and Schroeder's translation of Don Antonio Cordero's 1796 account of Apaches in the vicinity of El Paso (1957:338-339) shows that these groups were characterized by high mobility, reliance on a variety of wild plant and animal resources, and rather minimal cultivation of domesticated crops. Crops were pot-irrigated (Matson and Schroeder 1957:fn12). Fire drives of game were also practiced during the summer months (Matson and Schroeder 1957:344), during which areas in excess of nine square leagues were burned.

During this period, the Socorro (1815) and Pedro Armendaris #34 and #35 (1820) grants were established. Later Anglo accounts, however, indicate that these settlements struggled throughout much of their early history.

1.3.2.2 Mexican Period (1821-1846)

The Mexican Period in the southern portions of the project area were typified by establishment of a number of new land grants (Bowden 1971; Williams 1986:105). These included, in chronological order, Santa Teresa (1790), Canutillo (1824), Bracito (alt. Brazito, 1824), Doña Ana Bend Colony Grant (1844), Refugio Colony Grant (1850), Mesilla Civil Colony Grant (1852), José Manuel Sanchez Baca Grant (1853), and the Santo Tómas de Yturbide Grant (1853). The almost immediate acquisition of this region by the United States under the Treaty of Guadalupe-Hidalgo (1848) and subsequent Gadsden Purchase(1854) rendered the Mexican Period in this part of the project area almost moot. Accordingly, discussion of events during this period will be limited.

Archaeological investigations reveal that post-Revolt Spanish villages tended to be situated in floodplain settings (Marshall and Walt 1984:259). As a result, settlements were periodically destroyed due to flooding and most underwent a succession of rebuilding events. Among the named settlements were Alamillo, Bosque Bonito, Bosquecito, Bowling Green, Contadero, Cantarecio, Contreras, Mr. Crabb's Rancho, Bigs' Rancho, Elmendorf, El Tajo, El Trasquilla, Escondida, La Joya/Sevilleta, La Joyita, La Mesa de San Marcial, La Parida, Las Huertas, Las Cañas, Latear-Los Balen Buelas, Lemitar, Luis Lopez, Los Torreones, Milligan Ranch, Paraje, Polvadera, Pueblito, Sabinal, Sabino, San Acacia, San Albino, San Antonio, San Francisco, San Marcial, San Pedro, Socorro, Tiffany, Turato, and Valverde (Marshall and Walt 1984:259-287).

Much of this period in the southern project area was typified by Mescalero Apache raiding of outlying Mexican settlements, including the newly-established settlements in the Mesilla Valley. Situated in their traditional homeland in the Sacramento Mountains, the Mescalero raided westward across the Tularosa Basin into the Rio Grande (Dobyns 1973:Map2). By the early eighteenth century, other nearby tribes—notably the Utes and Comanches— had acquired horses and firearms. This ushered in a period of protracted, intense warfare among native peoples during which the Mescalero found themselves caught between the Spaniards along the Rio Grande to the west and Plains Indians to the east (Dobyns 1973:18-21). The collapse of the Spanish Empire in 1823, accompanied by replacement with Mexican authorities, caused yet another outbreak of warfare. Mexican government practices were, at best, ineffective along the northern frontier, allowing Indian groups—including the Mescalero—to resume raiding all across the frontier (Dobyns 1973:33-37). Raiding continued to typify Euro-Indian relations until 1850 and the project area remained largely unoccupied by Euro-American peoples through much of the eighteenth and nineteenth centuries.

To the south, in El Paso, changes in the mainstem of the Rio Grande sometime after 1827 led to a westward shift in the river channel that placed the towns of Ysleta, Socorro, and San Elizario on the left bank of the Rio Grande. Largely as a result of the "capture" of these towns, the spatial extent of settlements and irrigation systems in the El Paso valley expanded greatly. This change in the location of the mainstem of the Rio Grande also destroyed some of the agricultural lands in El Paso and was the catalyst for establishing the land grants in the Mesilla Valley listed above.

1.3.2.3 Euro-Anglo Period (1846 - present)

In 1846, Doniphan's California Column entered New Mexico, ushering in a new era in the region's history. With the subsequent defeat of the Mexican Army, New Mexico officially became a territory of the United States.

Conditions during the period between 1848 and the outbreak of the Civil War remained largely unchanged from those observed during the Mexican Period. Hispanic settlements were very few in number and still concentrated mostly in the Mesilla Valley, while Anglos settled largely centered in existing towns and villages. From 1848 to 1880, virtually all of the Rio Grande floodplain between modern-day Las Cruces, New Mexico, and El Paso, Texas, had been claimed by the U.S.

This period of upstream expansion into the Mesilla Valley of New Mexico was followed by a gradual expansion through the 1880s into downstream portions of the Lower Valley of El Paso that previously were unoccupied (Emory 1857:90). At least part of the lag in this expansion process can be attributed to the depredations of Apache Indians. Only after the Apaches were finally subjugated by U.S. troops in1881 was settlement in the Lower Valley possible. This supposition is confirmed by detailed histories showing that towns in the southeastern portion of El Paso County were not occupied until the later nineteenth century.

Development in the southern reaches of the planning area began during the later portion of the nineteenth century. Among the most important factors affecting development in the region was (1) resolution of water disputes between the United States and Mexico and (2) the appearance of large-scale irrigation projects under the auspices of the Bureau of Reclamation. These two processes are discussed in more detail below.

The catalyst for explicit consideration of water allocations between the U.S. and Mexico was an inadvertent outgrowth of the first effort to construct a dam on the Rio Grande. A local New Mexican businessman, Nathan Boyd, formed the Rio Grande Dam and Irrigation Company in 1895 with the express intent of appropriating all of the water of the Rio Grande and building a water storage facility in the vicinity of Engle, New Mexico. Shortly, thereafter, Boyd arranged for a group of English financial backers to take over control of the company while preserving much of its original intent.

According to the original prospectus, the Rio Grande Irrigation and Land Company, Ltd. was "...formed to acquire, by lease and assignment, the franchise rights, water rights, right of appropriating the waters of the Rio Grande (United States of America), contracts, properties, and undertaking of the Rio Grande Dam and Irrigation Company, and for the purposes of irrigating, colonizing, and improving the lands in the famous Rio Grande Valley, between Engle, New Mexico (sic) and Fort Quitman, Texas (sic)." Dam sites were proposed at Elephant Butte, Rincon, and Fort Selden, New Mexico (Mills 1896 in Follett 1898:12).

The Mexican government responded almost immediately that this project violated the Articles of the 1852 and 1884 agreements between the United States and Mexico inasmuch as the dam proposed by Boyd would adversely affect the navigability of the Rio Grande. Although this scheme foreshadowed the eventual construction of the Elephant Butte Dam, subsequent litigation (*United States of America vs. Rio Grande Irrigation and Land Company, Ltd.*) prevented the company from continuing its plans. Nevertheless, this proposed dam crystallized the problems associated with water allocations between the U.S. and Mexico.

The late nineteenth century and early twentieth centuries in the southern part of the project area were characterized by substantial growth due, in part, to passage of the Homestead Act (1862) and, later, the Reclamation Act (1902). The Homestead Act effectively promoted settlement by allowing up to 160 acres of public lands to be claimed by individuals and, after five years of improvements, to pass into private hands. The Reclamation Act (1902) supported settlement across the West by inaugurating large-scale water projects—notably Elephant Butte Dam—to stabilize water supplies for the newly arrived homesteaders.

The second factor that altered forever the southern reach of the project area was passage in 1902 of the Reclamation Act. Appropriations of $1 million for the project, initially to consist only of construction of the Elephant Butte Dam, were provided by Congressional authority on March 4, 1907 (34 Stat. L., 1357). Shortly thereafter, continued funding was provided to reconstruct much of the irrigation system that would eventually be supplied with water from Elephant Butte Dam (Reclamation 1907:221).

The first of these reconstruction efforts to be authorized under the terms of this Act was the Rio Grande Project, which included agricultural lands in both Texas and New Mexico. In general, the overall Bureau of Reclamation (Reclamation) strategy focused on consolidating formerly distinct canal systems into fewer, larger systems. In the Mesilla Valley, the Doña Ana and Mesilla canals—originally constructed in the mid-nineteenth century—formed the backbone of the initial consolidation and reconstruction of irrigation systems. In the El Paso valley, the Franklin Canal also constructed in the nineteenth century became the backbone of this system. In both the Mesilla and El Paso valleys, new canal segments were constructed to connect the alignments of smaller community ditches these backbone canal systems. In effect, that earlier small community ditches became laterals within a much larger system of water distribution canals (Reclamation 1919:226). This simplified the problem of conveying water to farms throughout the region and, moreover, did not require Reclamation to obtain large amounts of new canal right-of-way.

Although this strategy was largely successful, the rapid creation of new agricultural lands throughout the valley was accompanied by an increased demand for lateral canals to supply water for these new lands. As noted above, by 1917 Reclamation abandoned its initial approach of simply trying to (1) provide water to large main canals that could then (2) be managed by community acequias. This strategy simply did not work.

By 1918-1919, Reclamation agreed to provide or construct additional lateral canals subject to two constraints (WPRS 1981:1052). First, laterals would be constructed only if the lands to be served were greater than or equal to 160 acres in size. Second, Reclamation agreed that farmers would not have to construct more than 0.5 miles of the lateral. So, if a farmer cultivated 160 acres in a parcel that was at some distance from the nearest lateral, the farmer would construct the last 0.5 miles of the lateral, while Reclamation would construct the balance to connect a lateral to these fields.

The impact of this policy change is reflected by numerous agricultural statistics. One particularly telling statistic may be found in the Annual Reports of the Bureau of Reclamation (Reclamation 1921:68). Specifically, there was a gradual decrease in the ratio of irrigated acreage to total canal mileage

(Reclamation 1916:337; 1920:295; 1925:85). In 1910, immediately before Reclamation inaugurated its reconstruction program, the average number of acres per canal mile in the El Paso region was 3,767. By 1915, when the initial El Paso component of the reconstructed system was largely completed, the average number of acres per canal mile had declined to 769. By 1981, the ratio of irrigated acres to total canal mileage was 244 (WPRS 1981:1054).

1.4 Projected Impacts and EIS Alternative Evaluations on Cultural Resources

Of the 17 reaches comprising the entirety of the planning area, FLO2D discharge modeling indicates that potential impacts will be limited to only seven (7) reaches. The area of potential effect (APE) for cultural resources, as well as other issues, will be limited to Reaches 7–14. The remainder of the upstream (Reaches 1–6) and downstream (Reaches 15–17) portions of the project area would not be affected by any of the planning alternatives.

For cultural resources specifically, potential impacts revolve primarily around overbank flooding that could adversely affect prehistoric and historic archaeological sites. Within the broad definition of overbank flooding are a variety of sub-issues, each of which have the potential for adversely affecting cultural resources. These include:

- How many cultural resources will be affected by overbank flooding?
- How long will cultural resources be inundated during the 40-year modeling period used during this project?
- Will channel erosion associated with overbank flooding exacerbate adverse impacts to cultural resources?
- Are the characteristics of sites that may be adversely affected similar from reach to reach and alternative to alternative?

To begin analyzing alternative-specific impacts to cultural resources, it is first necessary to delineate the character of the reaches making up the planning area and the character of prior archaeological research completed in each of these reaches (**Table O-1.8**). Reaches vary considerably in size, ranging from as little as 37,000 acres (Reach 11) to approximately 440,000 acres (Reach 14). There are equally significant differences in the amount of acreage subject to prior archaeological survey. The absolute amount of survey coverage varies between as little as 2,000 acres (Reach 11) to more than 28,000 acres (Reach 14). The percentage of each reach subject to prior archaeological surveys varies from a low of 4 percent (Reach 13) to as much as 18 percent (Reach 9).

Given the variable amount of prior survey coverage, the number of known archaeological sites varies considerably from reach to reach. Accordingly it was first necessary to standardize archaeological data into site densities; for purposes of these analyses, site density was calculated on a 100 acre basis (i.e., number of sites/100 acres). Site density varies from a low of 2.01 sites/100 acres (Reach 14) to a high of 12 sites/100 acres (Reach 9).

Table O-1.8. Basic Parameters for Cultural Resources in the Planning Area

Reach	Acres per Reach	Acres Surveyed	Number of Known Sites	Percent of Reach Surveyed	Multiplier	Site Density per 100 Acres	Projected Sites per Reach	Number of Known Sites Inundated	Percent of Known Sites Inundated	Projected Sites to be Inundated
2		0	0	0%	—	—	—	—	—	0
3	271,015	3,254	472	1%	83.29	14.50522	39,311	—	0%	0
4	38,664	2,777	47	7%	13.92	1.69	654	—	0%	0
5	76,914	446	131	1%	172.45	29.37	22,591	—	0%	0
6	179,061	15,742	748	9%	11.37	4.75	8,508	—	0%	0
7	105,231	8,877	720	8%	11.85	8.11	8,535	5	0.7%	59
8	52,847	4,590	219	9%	11.51	4.77	2,521	3	1.4%	35
9	97,109	17,855	2142	18%	5.44	12.00	11,650	7	0.3%	38
10	11,7624	19,331	608	16%	6.08	3.15	3,700	2	0.3%	12
11	37,060	1,991	154	5%	18.61	7.73	2,867	0	0%	0
12	133,422	18,316	653	14%	7.28	3.57	4,757	5	0.8%	36
13	161,073	6,417	210	4%	25.10	3.27	5,271	3	1.4%	75
14	439926	28,367	571	6%	15.51	2.01	8,855	15	2.6%	233
15	102,247	8,200	204	8%	12.47	2.49	2,544		0%	0
16	358,484	8,309	721	2%	43.14	8.68	31,107		0%	0

* Highlighted reaches subject to potential inundation under alternatives; all other reaches unaffected and excluded from analyses.

Estimates of the number of archaeological sites likely to be inundated in each reach were estimated using a three-step iterative analysis as follows:

(1) First, the number of known sites shown to be inundated based on FLO2D output was divided by the total number of known sites to generate reach–specific inundation rates. For example, of the 571 known sites in Reach 14 (Number of Known Sites), a total of 15 sites (Number of Known Sites Inundated) were shown to be inundated by the FLO2D output. This indicates that 2.6 percent of all known sites in Reach 14 would be inundated.

(2) Second, the projected total number of archaeological sites in each reach was estimated by multiplying the site density by the total number of acres in each reach. This necessarily assumes that site distributions are uniform with reaches.

(3) Finally, estimates of the total number of sites likely to be inundated were obtained by multiplying reach–specific inundation rates by the estimated total number of sites in each reach.

Using this approach, anywhere from zero sites (Reach 11) to 233 sites (Reach 14) are projected to be potentially inundated under one or more of the EIS alternatives.

At the same time, different alternatives may result in different inundation rates for any given reach. To estimate these differentials, alternative–specific and reach–specific inundation rates were measured using FLO2D output (**Table O-1.9**). Put more simply, the number of known sites that would be inundated were tallied for each reach under each of the EIS alternatives. The estimated total number of sites was multiplied by proportion of known sites subject to inundation in a given reach under a given alternative to provide estimates of the total number of archaeological sites that would be inundated. This was repeated for each reach and each alternative.

An analysis of variance indicates that there are no significant differences between alternatives with respect to the number of prehistoric and historic sites potentially subject to adverse impacts associated with periodic inundation ($F_{6,42} = 1.56$, $p = 0.18$ for known sites and $F_{6,42} = 1.05$, $p = 0.41$ for projected numbers of sites). Alternatives are expected to lead to the inundation of between 383 (Alternative D-3) to upwards of 465 (Alternative E-3) archaeological sites. For all of the alternatives, average inundation days vary from a low of 2.03 (Alternative B-3) to 5.06 (Alternative I - 1) days per annum.

Analyses of channel erosion across the reaches likely to be affected by overbank flooding found few significant differences between the EIS alternatives (Appendix H). For purposes of this analysis, it is assumed that channel erosion affecting archaeological sites is normally distributed across reaches and alternatives. Of all the alternatives, the alternative having the lowest combination of inundated site numbers and annual number of inundation days is Alternative B-3. Alternative D-3 and Alternative I-3 have the next lowest combinations of impacts.

1 **Table O-1.9. Alternative Number and Reach–Specific Inundation of Archaeological Sites**

Reach	No Action Alternative - Known Sites	No Action Alternative - Projected Sites	Alternative B-3 – Known Sites	Alternative B-3 – Projected Sites	Alternative D-3 – Known Sites	Alternative D-3 – Projected Sites	Alternative E-3 – Known Sites	Alternative E-3 – Projected Sites	Alternative I-1 – Known Sites	Alternative I-1 – Projected Sites	Alternative I-2 – Projected Sites	Alternative I-2 – Projected Sites	Alternative I-3 – Known Sites	Alternative I-3 – Projected Sites
7	5	59	4	47	5	59	4	47	5	59	5	59	4	47
8	3	35	2	23	2	23	2	23	2	23	2	23	2	23
9	7	38	7	38	7	38	7	38	7	38	7	38	7	38
10	1	6	1	6	1	6	2	12	1	6	1	6	1	6
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	3	22	4	29	2	15	5	36	3	22	3	22	2	15
13	1	25	3	75	1	25	3	75	1	25	1	25	1	25
14	15	233	14	217	14	217	15	233	15	233	15	233	15	233
Total	35	418	35	436	32	383	38	465	34	406	34	406	32	387

The preceding analyses have focused primarily on variations in the numbers of archaeological sites potentially affected under each of the EIS alternatives. Each of the EIS alternatives has impacts on these sites, most related to overbank flooding. The second analysis focuses on potential variability in the frequency and duration of inundation of these sites.

The annual frequency of overbank flooding varies considerably between alternatives. For each of the EIS alternatives, **Figure O-1.7** shows mean numbers of years that sites will be inundated. There are two basic groups inherent in these data. The first group (Group 1) consists of the "Baserun" conditions and conditions expected under Alternative I-1 or Alternative I-2. The second group (Group 2) consists of Alternatives B-3, D-3, E-3, and I-3 which exhibit no statistical differences between pairs, but which differ significantly from alternatives in Group 1.

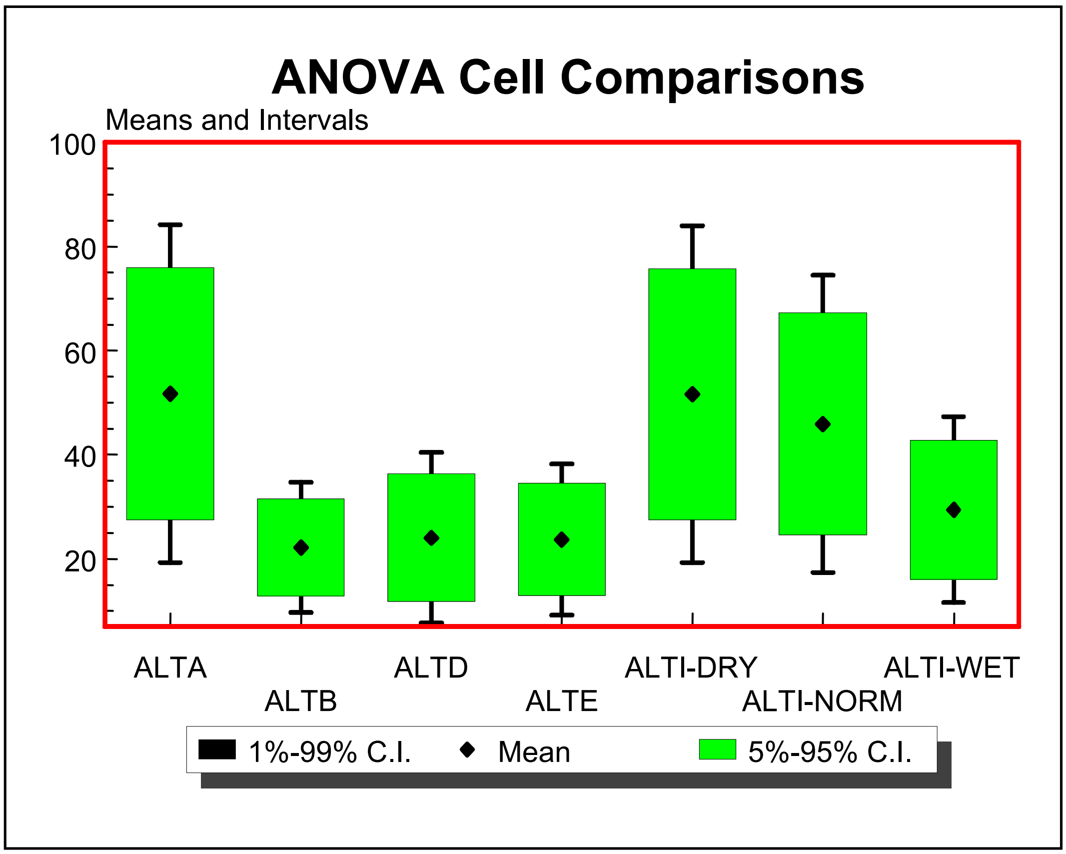


Figure O-1.7. Comparison of Inundation-Years by Alternative

Similarly, the expected duration (inundation days) of overbank flooding varies considerably between alternatives (**Figure O-1.8**). It should be emphasized that inundation days include only those days when overbank flooding greater than or equal to 0,5 ft would occur. Accordingly, estimated inundation days should be viewed as quite conservative. As with inundation years, there are three groups inherent in inundation-day data. There are no statistically significant differences in inundation days between Baserun conditions and Alternatives B-3 and D-3. The second group (Group 2) consists of Alternatives E-3, I-1 and I-3. Alternative I-2 differs significantly from all other alternatives.

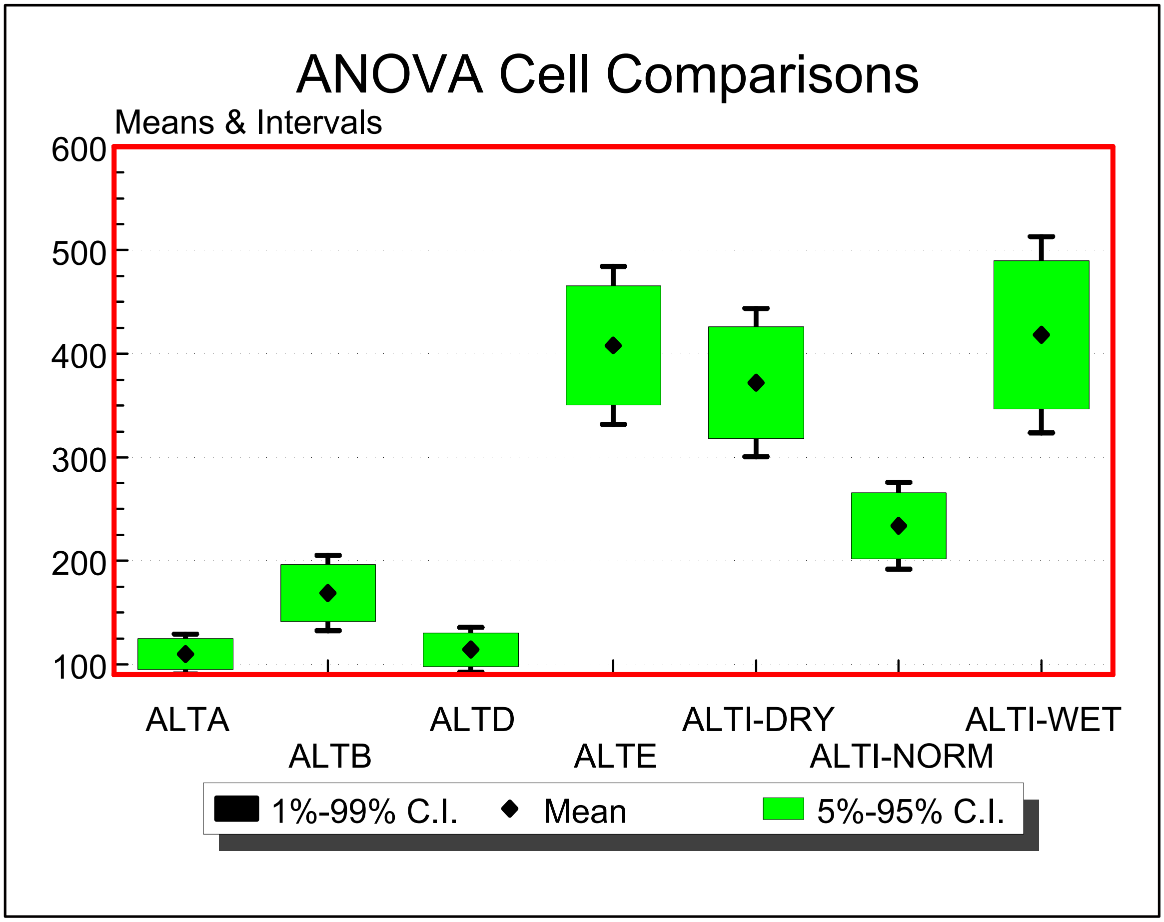


Figure O-1.8. Comparison of Inundation-Days by Alternative

A cross-tabulation of inundation years and inundation days provides a reasonable basis for selecting the alternative which minimizes both the frequency and duration of inundation of cultural resources (**Table O-1.10**). As is evident, Alternative D-3 minimizes the potential impact of inundation frequency and duration.

Table O-1.10. Cross-Tabulation of Alternatives by Inundation Years and Inundation Days

					Inundation Years
Inundation Days	22	24	29	46	52
109					No Action
114		ALT D-3			
169	ALT B-3				
234				ALT I-2	

	Inundation Years				
Inundation Days	22	24	29	46	52
372					ALT I-1
408		ALT E-3			
418				ALT I-3	

The final analysis focuses on qualitative site characteristics such as (1) eligibility for inclusion on the National or State Register of Historic Places, (2) whether the sites contain structural remnants, or (3) the ages of the sites likely to be affected. Of the 37 known sites that would be affected, nine (24 percent) are currently on either the State or NRHP. The purpose of this analysis is to determine whether the subset of archaeological sites affected by EIS alternatives differs significantly from the population of sites across the wider region in which the planning area is situated.

Of the 37 known sites affected by EIS alternatives, nine (24 percent) are on either the State or NRHP. Another 27 sites (73 percent) have no eligibility determination (i.e., they may or may not be eligible). One site is not eligible for inclusion on either of these registers. There are no differences between EIS alternatives with respect to the numbers of sites on or potentially eligible for inclusion on the NRHP.

Of the 37 known sites affected by EIS alternatives, 31 (84 percent) contain structural remnants. Projecting to a maximum of 465 impacted sites under Alternative E-3, a total of 391 structural sites may be adversely impacted. For the 6,839 sites that are known in the broader region, only 64 percent contain structural remnants. Thus, EIS alternatives would intersect at structural sites in proportions roughly similar to proportions of such sites in the broader region.

Of the 6,839 known sites in the broader region, almost half (49 percent) are prehistoric in age, with an additional 13 percent related to historic occupations (**Figure O-1.9**). Projections from the known sites that would be affected indicate that only 27 percent are prehistoric in age, while 12 percent are related to historic occupations. Perhaps the largest difference between the known sites that would be affected and the regional population of sites revolves around sites having both prehistoric and historic occupations. Among the known sites that would be impacted, 21 percent have both prehistoric and historic components. In the region as a whole, these comprise less than 5 percent of known sites. Accordingly, it is likely that prehistoric and sites of unknown age will be over–represented in the project reaches compared to the region as a whole.

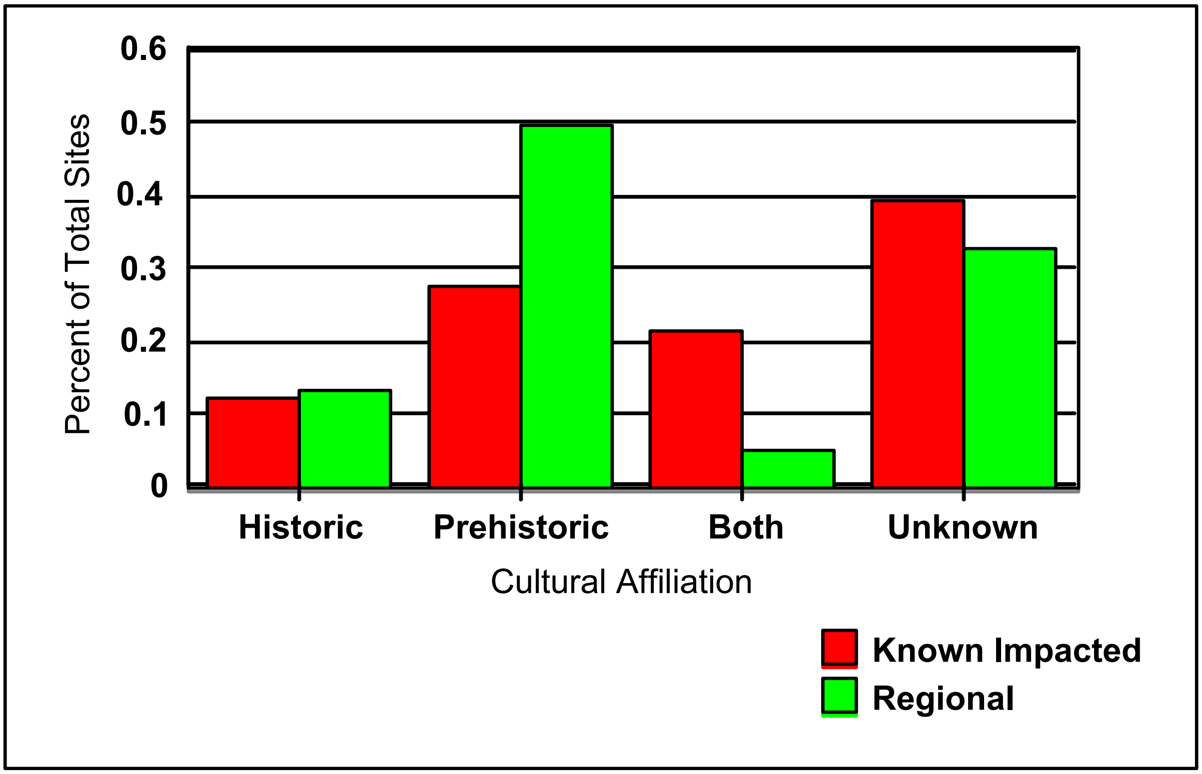


Figure O-1.9. Known Sites in the Broader Region

In summary, this discussion has shown that (1) there are no significant differences between EIS alternatives with respect to the number of archaeological sites that would potentially be affected (**Table O-1.11**); (2) there are significant differences between EIS alternatives with respect to the number of years (frequency) and number of days per year (duration) that archaeological sites will be inundated; (3) the impact of channel erosion on archaeological sites does not vary between EIS alternatives; and (4) there are no significant differences between EIS alternatives with respect to the attributes (e.g., NRHP status) of archaeological sites that might be affected. Based on these findings, implementation of proposed Alternative D-3 or Alternative B-3 would pose the least deleterious effects on cultural resources in the APE of this Review and EIS.

Table O-1.11. Final Weighting of Alternatives Based on Impacts to Numbers of Cultural Resources

	No Action Alternative	Alternative B-3	Alternative D-3	Alternative E-3	Alternative I-1	Alternative I-2	Alternative I-3
Total Sites Inundated	418	436	383	465	406	406	387
Relative Rank: Sites (xi / minimum)	1.09	1.14	1	1.21	1.06	1.06	1.01
Average Days/Annum Inundation	4.25	2.03	3.32	2.98	5.06	4.42	3.37
Relative Rank: Days (xi / minimum)	2.09	1.0	1.64	1.47	2.49	2.18	1.66
Overall Rank (Sites X Days)	2.28	1.14	1.64	1.78	2.64	2.31	1.68
Final Rank	6.0	.0 Least	3.0	4.0	.0 Most	5.0	2.0

1.5 Mitigation Measures

For all the alternatives, site inundation rates would be greatest in Reach 14. Indeed, inundated sites in Reach 14 comprise between 55 percent of estimated sites (Alternative E-3) to upwards of 90 percent (Alternative I-3) of estimated sites. Reaches 13, 7, and 9 would also show elevated inundation rates depending on specific alternatives, albeit at rates considerably lower than for Reach 14.

This logically suggests that mitigation measures, regardless of the preferred alternative that is finally selected, should focus on preventing overbank flooding in Reach 14. The precise nature of such measures can be determined in consultation with various lead agencies. Depending on the preferred alternative, measures designed to prevent overbank flooding should also be implemented in Reach 13 and Reach 7.

Alternatively, in the event that overbank flooding should emerge as a desired goal of changes in water operations (e.g., for restoration of riparian habitat), mitigation measures might include construction of barriers to prevent flooding of cultural resources. These may take the form of cofferdams or other similar structures that would prevent or limit overbank flooding of cultural resources.

Finally, if overbank flooding is desirable and barriers cannot be constructed, it is recommended that archaeological excavations be conducted at those sites where flooding is likely. This mitigation program could be phased so that sites in the greatest danger of flooding would be excavated first, followed by excavations at sites that are progressively less subject to overbank flooding

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APPENDIX P
DECISION SUPPORT PROCESS AND DATA QUALITY ANALYSIS

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1.0 Decision Analysis

1.1 Decision Support

The Upper Rio Grande Water Operations Review and EIS (Review and EIS) evaluated impacts on the human and natural environment for 22 possible water operations alternatives analyzed over a 40-year planning period. With three joint lead agencies (JLAs), five cooperating agencies and tribal governments, more than twenty actively participating stakeholders and tribal representatives, and over 400 interested stakeholders, the selection of a preferred alternative is a complicated process.

Reclamation and the Corps operate facilities for different purposes and objectives and must balance their legal responsibilities with respect to the environment, endangered species, Indian Tribes, international treaties, water contractors, and the protection of other resources. The NMISC has legal mandates regarding water deliveries for interstate Compact compliance and protection of water rights. Tribal and private stakeholders have interests regarding property rights for water rights and lands, water quality, and environmental and cultural resource preservation. With so many interests, competing legal mandates, and the varying water values represented, selecting a preferred alternative for this Review and EIS is complicated (USWRC 1983).

Also complicating decision-making are traditional assumptions that the “most likely” or “expected” values for impacts provide an appropriate basis for evaluating and comparing alternative plans. A more robust evaluation could include considerations for data quality, parameter ranges for impacts, and the implications of the uncertainties as they relate to the evaluation of alternatives. When factoring data quality, uncertainty, and risk in the analysis, the “best choice” may be less obvious. This Review and EIS attempts to understand and disclose the current state of data quality, the range and propagation of uncertainty, and how they affect the decision process leading to the selection of a preferred alternative. The ultimate goal is to improve the quality of the decision made.

1.1.1 Methods

Faced with a complex, multi-faceted decision, multiple agencies and stakeholders, and competing issues and values, the JLAs selected a formal structured decision-making process to lend transparency to the selection of the preferred alternative.

The National Environmental Policy Act of 1969 requires that Federal, State, and local decision-makers consider and disclose the environmental implications of their proposed actions in order to allow decision-makers and the public to make informed decisions. NEPA also requires consideration of alternative strategies to achieve project objectives with consideration of the entire project in the context of other projects and the human environment. The JLAs also have responsibilities under the ESA in ensuring that their discretionary actions and operations do not jeopardize the continued existence of any Federally listed or proposed species, or result in adverse modification or destruction of designated or proposed critical habitat (Reclamation 2003; Corps 2003).

Water management agencies also have broad goals in moving from crisis-management to a longer-term sustainable operation of water resources that are sufficiently flexible to accommodate the multiple uses and needs in the river system (Corps 2002). Key science and data needs must be filled along multiple factors including water operations; water gaging; streamflow forecasting;

biological and biodiversity measures; land use and vegetation; cultural and tribal resources; and economic analysis. Data was integrated through the use of GIS database and data quality, quantity, and consistency were evaluated and factored into the analysis process.

Taking scientific analysis by each of the resource teams and translating that knowledge and analysis into an informed decision that selects a preferred alternative also required a structured process.

The decision process for making informed decisions in a complex situation can be broken down as follows:

- Identify the decision problem (Basis for Conducting this EIS)
- Identify the objectives (EIS Purpose and Need Statement)
- Identify the alternatives (22 action alternatives identified based on scoping and water operations review)
- Identify the consequences (Preliminary screening and detailed screening of alternatives)
- Adjust for the tradeoffs (Identification of impacts and mitigation)
- Identify the uncertainty (Evaluate data quality and propagation of uncertainty)
- Identify the risk tolerance (Uncertainties in alternative preference and JLA willingness to accept and manage risk)
- Select and implement the preferred alternative (Record of Decision and Adaptive Management Plan)

The decision process used to select alternatives for detailed analysis and subsequently perform the detailed analysis on the retained alternatives is depicted on **Figure P-1**.

The logical steps in developing the detailed decision structure were as follows:

- Identify the goal (Select an Alternative)
- Identify the factors and criteria important in satisfying the goal (Decision Criteria)
- Where appropriate, identify subcriteria and performance measures (Team Criteria)
- Use objective performance measures wherever possible (Performance Measures)
- Value the importance of the criteria (Ranks and Weights)
- Evaluate alternatives against the objective performance measures (Scores, Ranks, Weights)
- Check reasonableness (Tradeoff and Uncertainty Analysis)
- Finalize the decision (Executive Committee Concurrence)
- Document the results (Criterium Decision Plus V3.0)

This process needed to identify uncertainties and risks and provide a transparent assessment of tradeoffs involved in plan selection. Therefore, a decision support tool was needed to supplement and aggregate the information obtained from the suite of scientific models used for this EIS: URGWOM, FLO-2D, MODBRANCH, RMA-2, Aquatic Habitat Model, Water Quality Model, and economic models.

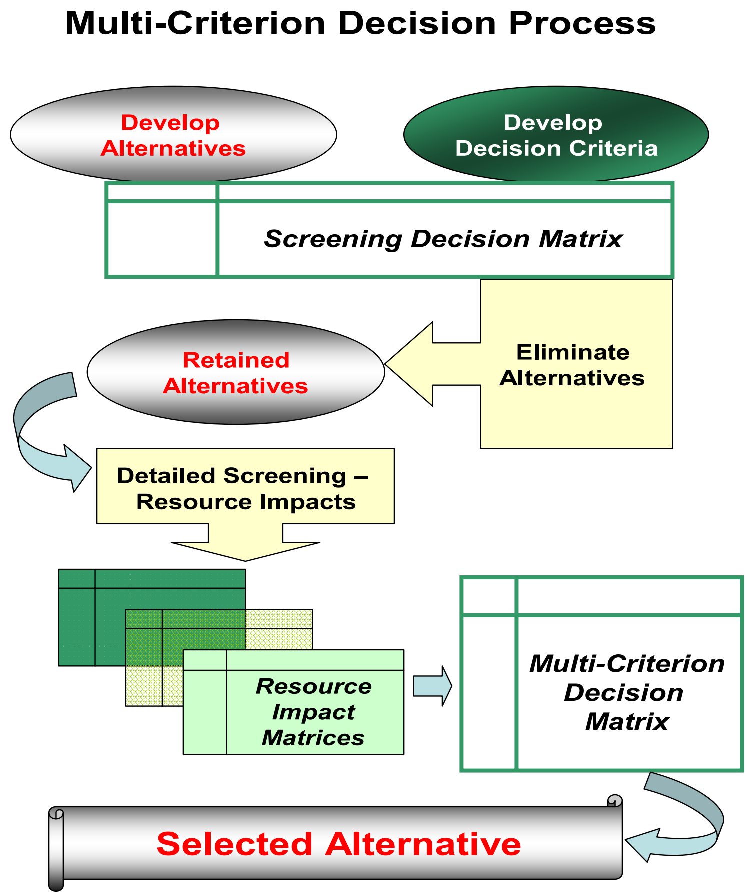

Figure P-1. Decision Process Diagram

Following a review of commercially available decision support software, Criterium Decision Plus (CDP) Version 3.0 distributed by InfoHarvest Inc. (InfoHarvest 2001) was selected to structure and document the decision process. CDP offered the following benefits: easy to use interfaces, visual hierarchies, modular construction for nested criteria, incorporation of uncertainty, tradeoff analysis, integration with GIS, export files compatible with Excel, and a free software reader allowing any stakeholder to examine the resulting decision models. The CDP decision analysis information is also being used in development of the Sandia National Laboratories dynamic simulation model. This model provides a user-friendly platform to ask "what if" questions and see the change in results. It is anticipated that the dynamic simulation model will be used in support of future public meetings presenting the results of this Draft EIS.

1.1.2 Developing Decision Criteria

Decision criteria were established prior to initiating the screening and detailed analysis of alternatives in order to disclose JLA and Steering Committee values and preferences among competing and potentially conflicting requirements and mandates. The list of potential criteria was developed during public scoping and alternatives development meetings and from the statements of project Purpose and Need as appended to the JLA Memorandum of Agreement (Appendix D).

Upon review of these criteria, the Executive Committee identified three minimum threshold criteria that had to be met in order for an alternative to be carried forward for detailed analysis. These criteria were considered to be equally important and were as follows.

(1) Meets water storage and delivery needs
(2) Meets interstate Compact and Treaty requirements
(3) Meets flood control and safe dam operations criteria

Threshold criteria were used as heavily weighted benchmarks by the Water Operations technical team in the preliminary screening of draft alternatives.

Prior to the screening of alternatives, decision criteria were established to differentiate between alternatives and to identify, in advance, the means by which decisions would be made. In this way, a non-biased ranking could occur without prejudging the relative merits of individual alternatives. Each JLA and members of the Steering Committee provided rankings for the decision criteria using three different methods.

- Fixed Point Rank (Numerical) – Assign points to each criterion up to a 100-point total
- Scaled Rank (Independent) – On a scale of 1 to 10, rank each criterion independently in terms of importance
- Ordinal Rank (Relative) – Rank from high (1) to low (9) the relative importance of each criterion

The weights for each of the three JLAs and the Steering Committee weights were assigned equal importance. The overall ranking of each criterion was obtained by an averaging of scores among the three ranking methods. The results are provided in **Figure P-2** and were posted to the project website in November 2003 (Corps 2003).

1.2 Preliminary Screening of All Alternatives

The Water Operations team performed the initial screening of the 22 alternatives considered for this Review and EIS. The team identified ten decision criteria that included the three JLA-designated threshold criteria. Technical performance was assessed by analyzing the URGWOM and MODBRANCH modeling results for each alternative over the 40-year planning period. The following are examples of parameters considered for threshold criteria performance.

- Water storage and delivery needs were evaluated by analyzing total reservoir storage and by water accounts (Rio Grande and San Juan-Chama (SJC) Project accounts)
- Compact compliance was evaluated by analyzing annual Otowi gage-based Compact delivery requirements versus actual water delivered to Elephant Butte Reservoir and an evaluation of New Mexico’s Compact credit/debit status at the conclusion of the 40-year period
- Flood Control and Safe Dam operations were incorporated into model rules concerning reservoir operations and were analyzed against physical channel capacity constraints, waivers, and other restrictions on water conveyance and storage

URGWOPS EIS DECISION CRITERIA

AGENCY or STAKEHOLDER: JLA & Steering Committees Combined
Date: 11/13/2003
Participants: COE, BOR, ISC & Steering Committee Participants

FINAL RANKINGS	DECISION CRITERION	Fixed Point Criterion Score (Numerical)			Scaled Criterion Rating (Independent)			Ordinal Criterion Rank (Relative)			OVERALL RANK
		JLAs	SC	RANK	JLAs	SC	RANK	JLAs	SC	RANK	
A	Meets Water Storage & Delivery Needs	Threshold			Threshold			Threshold			EQUAL
B	Meets Interstate Compact & Treaty Requirements										EQUAL
C	Meets Flood Control & Safe Dam Operations										EQUAL
1	Meets Ecosystem Needs	15	20	2	7.7	8.8	2	1.7	1	1	1
4	Provides Sediment Management	13	12	4	6.0	6.4	4	3.3	3	3	4
3	Preserves Water Quality	17	15	1	6.7	8.6	3	4.0	2	4	3
2	Provides System Operating Flexibility	15	12	3	8.7	8.1	1	2.7	5	2	2
7	Preserves Desirable Land Uses	4	8	8	4.7	6.9	6	7.7	4	7	7
8	Preserves Recreational Uses	9	6	7	4.0	5.4	8	7.3	9	8	8
6	Preserves Cultural Resources	12	7	5	4.7	4.8	7	6.0	8	6	6
9	Alternative is Fair and Equitable	4	9	9	3.3	5.4	9	8.7	7	9	9
5	Preserves Indian Trust Assets	11	9	6	5.3	6.3	5	3.7	6	5	5

ABBREVIATIONS:
URGWOPS = Upper Rio Grande Water Operations
EIS = Environmental Impact Statement
JLAs - Joint Lead Agencies
COE = U.S. Army Corps of Engineers
BOR = U.S. Department of Interior - Bureau of Reclamation
ISC = New Mexico Interstate Stream Commission
SC - Steering Committee - input from participants in November 13, 2003 meeting choosing to participate in ranking

Figure P-2 – Decision Criteria

Each alternative was scored on a scale of 1 to 10 relative to how well it performed on each technical performance measure. The performance score (scale of 1 to 10) multiplied by the criterion weight (percentage) summed across all criteria provided the overall alternative score (maximum = 100%). Alternatives were then ranked from high (1) to low (22) in overall performance and the top five alternatives were presented to the ID-NEPA team for concurrence in December 2003. The No Action Alternative was retained for detailed analysis in accordance with NEPA and CEQ requirements (CEQ; Reclamation 2000).

1.2.1 Detailed Analysis of Retained Alternatives

The individual decision criteria ranked by the JLAs and Steering Committee are the top tier hierarchy in the decision matrix. These decision criteria were expanded in detail by the individual ID-NEPA technical and resource teams. The technical criteria are summarized as second- and third-tier criteria assessed using explicit quantitative and qualitative performance measures, with underlying performance data founded in models and technical analyses. This detailed analysis process was shown on Figure DSS-1.

The ID-NEPA teams performed detailed analysis of the retained alternatives by developing a series of subcriteria and performance measures. Results of URGWOM, FLO-2D, Aquatic Habitat, MODBRANCH, GIS, and other modeling/analyses were used by the teams to evaluate the technical performance of each alternative over the 40-year planning period. The results of their detailed analyses were summarized in spreadsheets and translated into a decision hierarchy using performance measures and weights, as documented in the CDP decision model (**Attachment A**) and shown on the decision hierarchy presented on **Figure P-3**.

1.3 Results of Screening and Analysis of Alternatives

1.3.1 Preliminary Screening of Alternatives

The Water Operations team presented preliminary draft screening results for alternatives A-1 through H to the ID-NEPA team at the December 2003 monthly meeting. The Water Operations team recommended five alternatives be retained for detailed analyses: B-3, C-3, D-3, E-3, and the no action alternative. They also suggested that, based on similarities in performance, Alternatives C-3 and E-3 be combined into a single alternative, E-3, for detailed analysis.

Upon examination of this list of recommended alternatives in December 2003, the ID-NEPA team was concerned that all alternatives selected by the Water Operations criteria maximized upstream reservoir storage. They requested that a series of “I” alternatives be established to consider potential impacts of allowing more water in the river channel by capping upstream reservoir storage in Abiquiu Reservoir (20,000 and 75,000 acre-feet (AF)) and explicitly limiting Low Flow Conveyance Channel (LFCC) capacities to 500 and 1,000 cfs. Subsequent to this December 2003 ID-NEPA team meeting, the Water Operations team performed additional model runs to analyze alternatives I-1, I-2, and I-3 and incorporated these alternatives into their preliminary screening analysis as shown on **Figure P-4**. While the I-1 and I-2 alternatives were not ranked as high as the others, they were retained for detailed analysis at the express request of the ID-NEPA team. As a result, the alternatives selected for detailed analysis were: B-3, D-3, E-3, I-1, I-2, I-3 and the no action alternative.

As shown on Figure DSS-4, alternatives were rejected if they did not meet minimum performance standards for threshold criteria and/or if the sum of their weighted performance scores did not rank sufficiently high to merit further consideration.

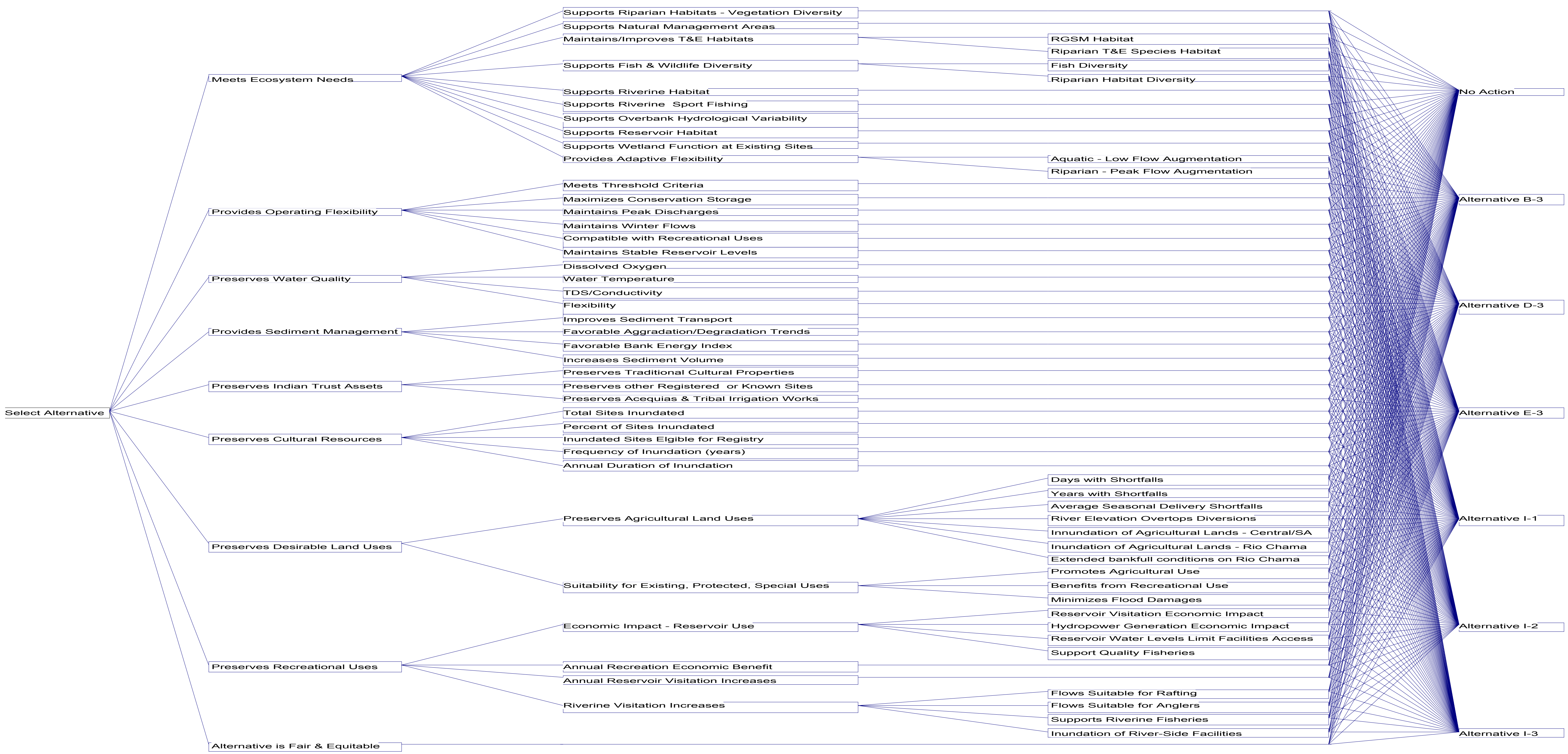

Figure P-3. Decision Hierarchy

DECISION SUPPORT: Alternative Performance vs. Water Operations Performance Measures

	Performance Measure	Compatibile w/Flood Control Operations	Compatibile w/Rio Grande Compact	Improves System Operational Flexibility	Supports Water Delivery	Maximizes Conservation Storage Opportunities	Maximizes Peak Discharge Opportunities	Maximizes Sediment Transport Opportunities	Supports Desirable Winter Flows	Supports Recreational Uses	Supports Stable Reservoir Levels		
	Threshold Criterion	X	X		X								
	Weight	0.20	0.20	0.15	0.15	0.10	0.08	0.05	0.04	0.02	0.01	Weighted Average Percent Met	Rank
	ALTERNATIVE												
1	**Plan G - No Action (Baseline)**	**7**	**4**	**5**	**8**	**0**	**6**	**6**	**5**	**5**	**5**	**52.80%**	**19**
2	Plan A1- Dry Hydrology Criteria	4	5	3	2	3	2	2	3	3	3	33.20%	22
3	Plan A2 - Normal Hydrology Criteria	4	5	4	2	7	2	2	1	1	1	37.30%	21
4	Plan A3 - Wet Hydrology Criteria	4	5	5	2	10	2	2	1	1	1	41.80%	20
5	Plan B1 - Dry Hydrology Criteria	6	7	6	7	3	5	5	4	4	4	57.80%	18
6	Plan B2 - Normal Hydrology Criteria	7	7	8	8	7	7	7	5	5	5	71.60%	16
7*	**Plan B3 - Wet Hydrology Criteria**	**9**	**9**	**10**	**8**	**10**	**8**	**9**	**5**	**5**	**5**	**87.40%**	**6**
8	Plan C1 - Dry Hydrology Criteria	7	8	6	8	3	6	6	5	5	5	65.30%	17
9	Plan C2 - Normal Hydrology Criteria	10	10	8	9	7	9	8	6	5	5	87.60%	5
10***	**Plan C3 - Wet Hydrology Criteria**	**10**	**10**	**10**	**10**	**10**	**9**	**9**	**6**	**5**	**5**	**95.60%**	**1**
11	Plan D1 - Dry Hydrology Criteria	10	8	7	10	3	8	8	5	5	5	78.40%	11
12	Plan D2 - Normal Hydrology Criteria	10	8	8	10	7	8	8	5	5	5	83.90%	8
2*	**Plan D3 - Wet Hydrology Criteria**	**10**	**10**	**10**	**10**	**10**	**8**	**8**	**5**	**5**	**5**	**93.90%**	**3**
14	Plan E1 - Dry Hydrology Criteria	10	10	6	8	3	9	9	5	6	5	79.40%	10
15	Plan E2 - Normal Hydrology Criteria	10	10	7	9	7	9	9	6	6	5	86.80%	7
16*	**Plan E3 - Wet Hydrology Criteria**	**10**	**10**	**9**	**10**	**10**	**9**	**9**	**6**	**6**	**5**	**94.30%**	**2**
17	Plan F1 - Dry Hydrology Criteria	10	8	5	10	0	9	9	6	6	6	74.40%	13
18	Plan F2 - Normal Hydrology Criteria	10	8	5	10	0	9	9	6	6	6	74.40%	13
19	Plan F3 - Wet Hydrology Criteria	10	8	5	10	0	9	9	6	6	6	74.40%	13
20**	**Plan I1 - Dry Hydrology Criteria**	**10**	**6**	**6**	**10**	**3**	**7**	**7**	**6**	**6**	**6**	**72.30%**	**15**
21**	**Plan I2 - Normal Hydrology Criteria**	**10**	**8**	**8**	**10**	**7**	**7**	**7**	**6**	**6**	**6**	**83.30%**	**9**
22*	**Plan I3 - Wet Hydrology Criteria**	**10**	**10**	**10**	**10**	**10**	**7**	**7**	**6**	**6**	**6**	**93.30%**	**4**

NOTES:

1. Performance Measure weights sum to 100 points total
2. Weighted Average Percent Met multiplies sums (scores * weights) for all measures
3. Alternatives are ranked from highest to lowest score
4. Top four alternatives selected for detailed analysis; supplemented by ID-NEPA Team dry and normal alternative selections

7*	**Alternative Selected by Water Operations Rankings for Detailed Analysis**
20**	**Alternative Selected by ID-NEPA Team for Broader Sepctrum Operations Analysis**
10***	**Alternative combined with E-3 for detailed analysis**

Figure P-4. Preliminary Screening

1.4 Detailed Analysis of Retained Alternatives

The detailed analyses of retained alternatives was performed on a resource-specific basis by the individual ID NEPA teams: Aquatic, Riparian, Geomorphology, Water Operations, Hydrology and Hydraulics, Water Quality, Cultural Resources, and Land Use etc. teams. Each team was responsible for the detailed evaluation of at least one top level decision criterion. In some cases, team evaluations were combined into a single decision criterion – for example, the criterion "Meets Ecosystem Needs" synthesized results from both the Aquatic and Riparian team evaluations. The detailed weighted and scored decision hierarchy is shown on **Figure P-5**. CDP decision model files and the CDP reader are provided in electronic format as Attachment A.

Each team provided its own subcriteria and performance measures linked through the hierarchy to the top tier decision criteria. In this way, uncertainty analyses at the performance measure level could be easily updated as to impacts on the selection of the preferred alternative. ID-NEPA team spreadsheets with actual values for explicit performance measures by river section and alternative, (e.g., acres of habitat area, duration of overbank flooding, peak flow duration, cumulative reservoir storage, recreation days, etc.) are provided in Attachment A.

Once a preferred alternative was identified, an evaluation of tradeoffs, uncertainty, reasonableness, and robustness was performed to aid in understanding the sensitivities in the selection process (Corps 2002; Corps 1997).

1.4.1 Uncertainty

Our environment is inherently variable (intrinsic variability) and we are continually evolving in our abilities to understand and describe these processes (knowledge variability). Floods and droughts are inherently unpredictable, but have tangible environmental, safety, and economic consequences. Hydraulic variability was incorporated into the 40-year planning model input hydrograph to simulate periods of drought and abundant rainfall (Appendix I, Water Operations). Geographic information system (GIS) analysis was used to document, on a river reach basis, the quality of data available for each resource that was used for analyses supporting this Review and GIS. The discussion of data quality as it relates to decision-making was provided in previous sections of this technical report. Estimates of predictive error associated with data inputs and modeling have lead to a 10 percent factor applied to identify significant change from baseline conditions. The magnitude of error also increases from upstream to downstream, with the largest predictive error associated with the San Acacia and Southern Sections.

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Figure P-5. Decision Analysis Scores

Decision Scores

Goal	Weights	Criteria	Weights	Performance Measure	Weights	SubCriteria	ALTERNATIVE SCORE						
							No Action	B-3	D-3	E-3	I-1	I-2	I-3
Select Alternative	20	Meets Ecosystem Needs	14	Supports Riparian Habitats - Vegetation Diversity		Supports Riparian Habitats - Vegetation Dive	63.6	44	65.4	57.8	89.3	76.9	58.3
			4	Supports Natural Management Areas		Supports Natural Management Areas	93.4	57.7	53.8	59.2	88.1	79.9	60
			8	Maintains/Improves T&E Habitats	43.5	RGSM Habitat	94.71	95.77	95.92	95.95	99.52	99.5	95.78
					56.5	Riparian T&E Species Habitat	70.1	59	53.6	66.4	77.7	70.1	53.5
			10	Supports Fish & Wildlife Diversity	78.5	Fish Diversity	82.76	69.59	74.85	72.94	75.52	86.91	91.12
					21.5	Riparian Habitat Diversity	76.7	57.4	70	62.2	87.1	75.2	63.5
			22	Supports Riverine Habitat		Supports Riverine Habitat	99.52	92.05	91.15	91.78	93.79	93.75	90.58
			2	Supports Riverine Sport Fishing		Supports Riverine Sport Fishing	99.32	98.25	98.76	98.48	100	99.43	98.39
			16	Supports Overbank Hydrological Variability		Supports Overbank Hydrological Variability	55.4	78.2	76	88.6	76.1	74.6	74.1
			10	Supports Reservoir Habitat		Supports Reservoir Habitat	92.91	83.55	80.52	80.81	77.12	66.69	64.83
			8	Supports Wetland Function at Existing Sites		Supports Wetland Function at Existing Sites	99.1	95	94.6	95	97.4	96.4	95
			6	Provides Adaptive Flexibility	50	Aquatic - Low Flow Augmentation	48.1	100	94.2	94.7	55.8	77.4	95.7
					50	Riparian - Peak Flow Augmentation	16	96	89	97	30	66	91
	17.78	Provides Operating Flexibility	37.5	Meets Threshold Criteria		Meets Threshold Criteria	50	83	89	94	58	72	95
			25	Maximizes Conservation Storage		Maximizes Conservation Storage	0	98	95	95	50	76	96
			20	Maintains Peak Discharges		Maintains Peak Discharges	83	90	87	88	85	100	88
			10	Maintains Winter Flows		Maintains Winter Flows	94	100	96	97	96	96	97
			5	Compatible with Recreational Uses		Compatible with Recreational Uses	100	92	92	90	95	92	90
			2.5	Maintains Stable Reservoir Levels		Maintains Stable Reservoir Levels	90	98	96	97	88	93	98
	15.56	Preserves Water Quality	34.57	Dissolved Oxygen		Dissolved Oxygen	99.75	90.75	92	93.25	93.25	94	93.25
			41.47	Water Temperature		Water Temperature	73	99.5	97	96.75	96.75	93.25	97
			23.04	TDS/Conductivity		TDS/Conductivity	88.25	100	98.5	98.5	98.5	98.5	98.5
			0.92	Flexibility		Flexibility	0	100	14.37	19.38	1.17	2.47	21.11
	13.33	Provides Sediment Management	25	Improves Sediment Transport		Improves Sediment Transport	100	76	77	76	87	82	77
			25	Favorable Aggradation/Degradation Trends		Favorable Aggradation/Degradation Trends	93	96	91	94	75	83	93
			25	Favorable Bank Energy Index		Favorable Bank Energy Index	99	90	90	89	95	92	89
			25	Increases Sediment Volume		Increases Sediment Volume	100	79	80	80	89	84	80
	11.11	Preserves Indian Trust Assets	40	Preserves Traditional Cultural Properties		Preserves Traditional Cultural Properties	50	75	50	75	66.67	66.67	66.67
			30	Preserves other Registered or Known Sites		Preserves other Registered or Known Sites	50	75	50	50	66.67	66.67	66.67
			30	Preserves Acequias & Tribal Irrigation Works		Preserves Acequias & Tribal Irrigation Work	50	75	50	50	66.67	66.67	66.67
	8.89	Preserves Cultural Resources	25	Total Sites Inundated		Total Sites Inundated	92	88	100	82	94	94	99
			20	Percent of Sites Inundated		Percent of Sites Inundated	86	83	97	73	92	92	100
			10	Inundated Sites Elgible for Registry		Inundated Sites Elgible for Registry	80	100	24	24	83	83	83
			20	Frequency of Inundation (years)		Frequency of Inundation (years)	46	100	100	100	46	55	86
			25	Annual Duration of Inundation		Annual Duration of Inundation	29	100	100	100	29	50	50
	6.67	Preserves Desirable Land Uses	50	Preserves Agricultural Land Uses	10	Days with Shortfalls	82.05	81.95	80.03	80.15	81.9	80.13	81.75
					10	Years with Shortfalls	49.38	50.63	49.08	50.63	50.63	49.08	49.08
					30	Average Seasonal Delivery Shortfalls	82.05	82	81.78	81.85	81.9	81.8	81.75
					10	River Elevation Overtops Diversions	57.9	66.5	61.7	59.6	56.7	58.8	59.6
					10	Inundation of Agricultural Lands - Central/S	96.6	97.05	95.88	96.83	95.65	96.2	96.78
					10	Inundation of Agricultural Lands - Rio Cham	90.23	89.9	83.97	86.27	80.37	83.63	85.9
					20	Extended bankfull conditions on Rio Chama	78	100	86.7	87.3	78.7	87.3	78
			50	Suitability for Existing, Protected, Special Uses	40	Promotes Agricultural Use	7.7	8.3	6.6	7.9	7.6	7.7	7.9
					30	Benefits from Recreational Use	5.3	5.6	5.9	6	5	5.5	6
					30	Minimizes Flood Damages	4	15	100	11	6	12	86
	4.44	Preserves Recreational Uses	40	Economic Impact - Reservoir Use	25	Reservoir Visitation Economic Impact	56	100	99	98	88	98	71
					25	Hydropower Generation Economic Impact	77	87	100	100	93	98	100
					45	Reservoir Water Levels Limit Facilities Acce	51.98	54.48	59.7	60	46.73	53.78	60.05
					5	Support Quality Fisheries	59.7	52.8	51.2	50.9	100	94.3	92.2
			20	Annual Recreation Economic Benefit		Annual Recreation Economic Benefit	56	100	99	98	88	98	71
			20	Annual Reservoir Visitation Increases		Annual Reservoir Visitation Increases	56	100	99	98	88	98	71
			20	Riverine Visitation Increases	53	Flows Suitable for Rafting	52	51	51	53	52	52	53
					32	Flows Suitable for Anglers	53.67	60.33	61.33	60.33	54.67	57.67	60.33
					11	Supports Riverine Fisheries	99.32	98.25	98.76	98.48	100	99.43	98.39
					4	Inundation of River-Side Facilities	100	100	98.33	100	95.67	99.17	100
	2.22	Alternative is Fair & Equitable				Alternative is Fair & Equitable	3	1	7	5	4	2	6

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While acknowledging the various sources and the magnitude of uncertainty in our performance analyses, single (expected) values were used in the current decision analysis. As indicated in the data quality discussion, in many cases there was insufficient statistical and probabilistic assessment of variability and quantitative incorporation of these uncertainties into our models and decision-making processes.

It is possible that in the future, the use of basic statistical descriptions of the data available could provide more robust knowledge of possible ranges in performance. Basic statistical measures such as the mean, median, maximum, minimum, standard deviation, variance, skew, kurtosis, etc. could offer a more realistic picture of alternative performance.

The uncertainty in each individual parameter, when aggregated into a decision matrix, filters up and is compounded, thereby introducing uncertainty and risk in the selection of a preferred alternative. Without considering uncertainty, each alternative has a single decision score. Incorporating uncertainty, there may be occasions where a lesser-ranked alternative may be the better choice, depending on the risk tolerance and management needs of the decision makers. Understanding and communicating the level of risk associated with the choice assists decision makers in selecting a preferred alternative that best fits their risk tolerance.

Figure P-6 depicts a cumulative density function plot showing the uncertainty associated with these alternative. The almost vertical data plots show the least uncertainty because they are based on single-value (expected value) inputs. If desired, these analyses could be expanded using the statistical analyses cited above. Depending on risk tolerances, managers could use uncertainty analyses to understand the magnitude of risk undertaken in selecting a given alternative.

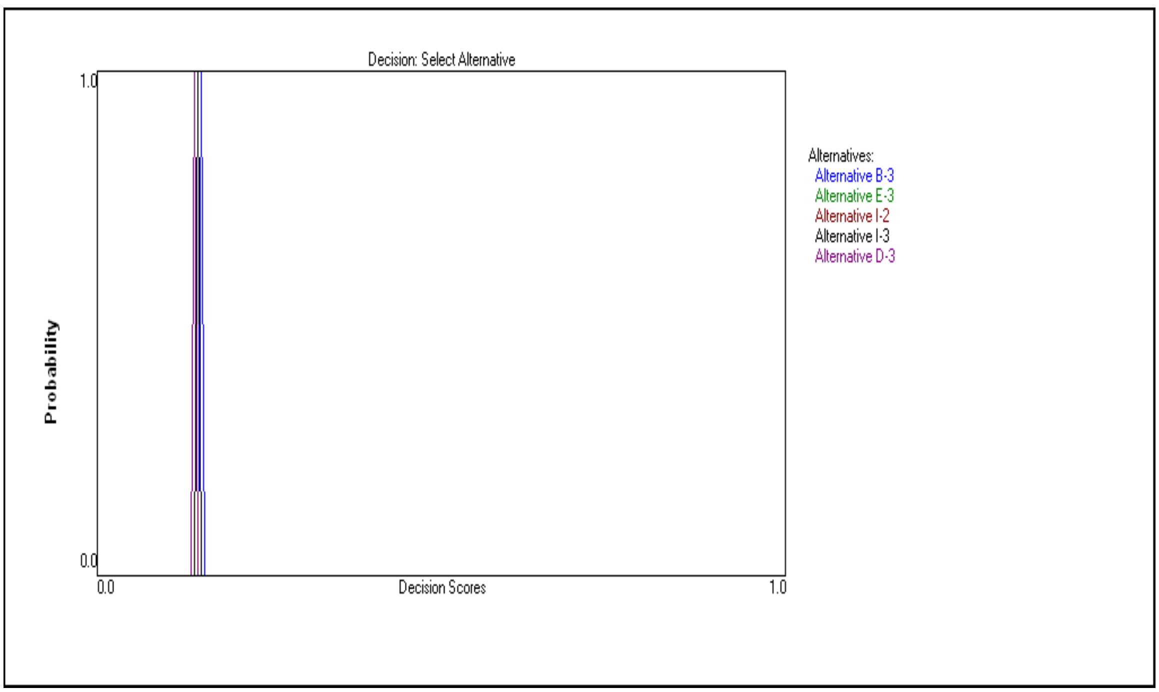


Figure P6. Cumulative Density Function Plot

Figure P-7 shows an example of direct comparisons available between individual decision criteria. In this case, the performance of alternatives with respect to supporting RGSM show that all alternatives provide between 90 and 100% maximum possible support. In contrast, performance for threshold criteria ranges from 50 to 100%, and only alternatives B-3, D-3, E-3, and I-3 offering better than 75% performance on these key parameters. When viewing the actual decision files using the model reader, direct comparisons can be made between any two criteria in the model.

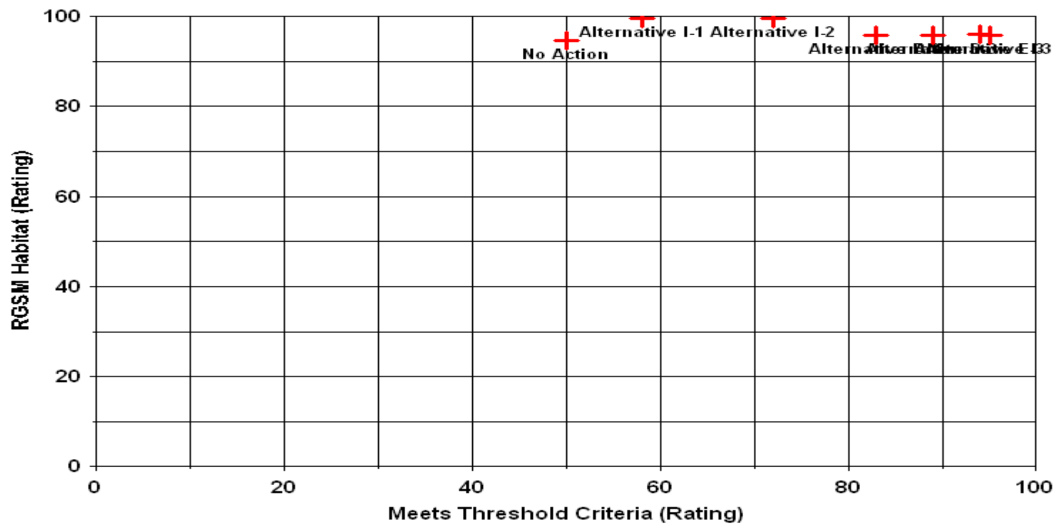


Figure P-7. Example of Direct Comparisons Between Criteria

1.4.2 Tradeoffs

The sensitivities to weights and ratings can also be evaluated depicting how selection of a preferred alternative depends upon the priorities of individual criteria. As shown on **Figure P-8**, the preferred alternative, B-3 shows the highest sensitivity towards the following criteria and measures (criterion-measure):

- Alternative is Fair and Equitable (3.1%)
- Preserves Water Quality - Flexibility (9.5%)
- Preserves Desirable Land Uses (14.4%)
- Preserves Indian Trust Assets (19.1%)
- Preserves Cultural Resources (26.5%)
- Meets Ecosystem Needs – Supports Natural Management Areas (4.7%)

In most cases, the next most-preferred alternative, I-3, would be selected if the priority or weight were to change more than the percentage identified. The alternative selection process is deemed to be robust in identifying a preferred alternative when the sensitivities to weights and ratings are subject to a greater than 5 % change in weighting before a new alternative would emerge as the preferred alternative. The evaluation of water operations alternatives under this EIS involved fairly sensitive discrimination between alternatives that typically reveal only slight differences in impacts. However, upon analysis of sensitivities, the selection of Alternative B-3 as the preferred alternative is shown to be reasonably robust, with only one parameter of sixty showing a less than 5 % sensitivity. The importance of alternative fairness and equity would need to decrease a further 3.1 percent to result in a change in alternative preference.

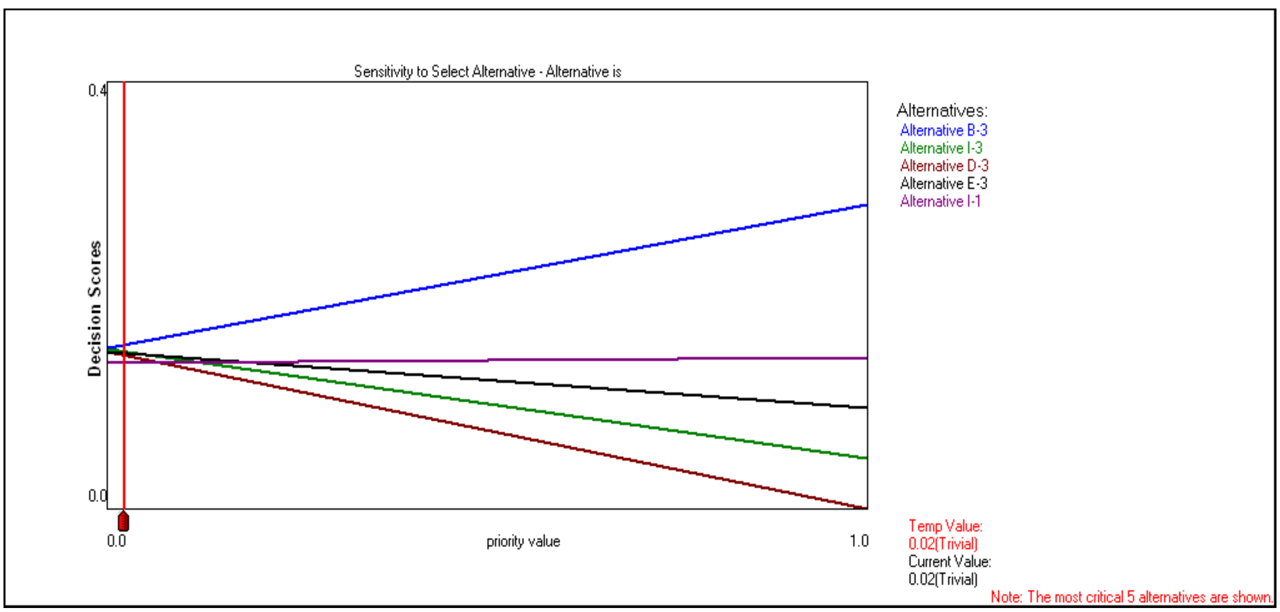


Figure P-8. Sensitivity by Weights

1.5 Selection of the Preferred Alternative

Examination of reasonableness in capturing the thinking process is needed to further understand the implications of the ultimate choice. Examining the contributions by individual criteria allows decision makers and stakeholders to understand the values and tradeoffs supported by each alternative.

The radar graph is a useful tool in discriminating unique alternatives based on distinct value differences from those alternatives that are essentially slight variations of the similar values and priorities. The radar diagram spokes represent each criterion used in the decision for the overall goal or theme. The best-performing alternative for a given goal or theme should maximize available area across all spokes of the radar diagram. Top performing alternatives for a given criterion will plot along the outward extremes of a single criterion spoke. Minimally performing alternatives will score towards the center of the diagram.

Determining whether the top scoring alternative is a hybrid solution scoring well across all criteria, as opposed to an alternative that favors an extreme for one top-ranked criterion, is important to decision-makers answering to many stakeholders. Where there are broad similarities among multiple alternatives, the choice of the best scoring alternative is easily supported. Where two top scoring alternatives have radically different patterns on the radar diagram, the choice of a preferred alternative in effect supports one value system over another. By analyzing the radar diagram, one can document the value-basis for alternative selection and be prepared to discuss the merits and trade-offs reflected by the preferred alternative.

Figure P-9 shows the radar diagram for the preliminary screening of the retained alternatives against threshold criteria and water operations criteria. Alternatives had to meet minimum requirements in threshold criteria for the water operations team to forward their selection to the ID-NEPA team. As shown on Figure DSS-9, alternatives B-3, D-3, E-3 and I-3 all met threshold criteria requirements, with alternative E-3 exhibiting the top rank at this stage. The ID-NEPA team added the I-1, I-2, and I-3 alternatives for detailed analysis based on a desire to provide a full examination of impact sensitivities in varying upstream storage allowances and operation of the Low Flow Conveyance Channel.

Figure P-10 shows alternative performance with respect to the three threshold criteria: 1) continued safety of dam and flood control operations; 2) meeting Compact deliveries; and 3) meeting contracted deliveries. Alternatives I-2, I-1, and No Action do not meet minimum criteria for meeting Compact Deliveries.

Figures P-11, P-12, and P-13 show the radar diagrams for the top three decision criteria: 1) meets ecosystem needs; 2) provides operating flexibility; and 3) preserves water quality.

As shown on **Figure P-11**, the ecologically preferred alternative is I-1. It delivers a hydrograph that is least encumbered by upstream storage and caps diversions to the LFCC at 500 cfs thereby leaving more water in the river channel in the San Acacia Section. However, this alternative offers less flexibility than others because there is the least upstream storage available for targeted delivery to ecosystem resources that could be used to provide additional water to augment peak flows, avoid intermittency, or provide late season supplementation for riparian interests.

The no action alternative was modeled with zero diversions to the LFCC, providing a best-case estimate for ecosystem impacts in the San Acacia Section. All other action alternatives were modeled exercising the full flexibilities offered. That is, upstream storage options were exercised whenever possible and LFCC diversions were conducted to the maximum allowed.

The preferred alternative, B-3, is the worst-ranked alternative from an ecosystem perspective, while being the top-ranked alternative for maximum conservation storage potential. Most ecosystem performance rankings compare B-3 at 2,000 cfs diversions to the LFCC against No Action with 0 cfs diversions. Therefore, ecosystem comparisons offer worst-best case comparisons in the San Acacia Section and did not account for the benefits of using stored conservation water at critical times of the year. Alternative B-3 performed well on riverine and reservoir habitat, hydrologic variability, and adaptive flexibility performance measures. Alternative B-3, in its present configuration, does not provide as much support for habitat diversity, but with increased channel capcities below Cochiti Dam, it offers the potential for carrying higher flows into the lower sections. Mitigation measures could be identified to use conservation water storage offered in this alternative to offset some of the undesirable seasonal impacts.

Operating flexibilities were weighted and ranked by from a water operations perspective as shown on **Figure P-12**. In this case, alternative B-3 offers mid-range water management flexibility by maximizing conservation storage opportunities, and offering higher peak discharge opportunities; alternative I-3 was ranked best for water management flexibility. The No Action Alternative is least desirable as it offers no flexibility in the amount of stored conservation water available to modify the duration and timing of water deliveries for Compact delivery and ecosystem needs.

From a water quality perspective, alternative B-3 is the top-ranked alternative offering the best combination of temperature, dissolved oxygen, and dissolved solids/conductivity conditions and the highest potential flexibility. However, this alternative ranked the worst with respect to dissolved oxygen availability. The second choice alternative for water quality was I-3, outranking B-3 on dissolved oxygen. The flexibility measure for water quality was the most sensitive criterion evaluated – and is one of the measures least likely to change in relative importance to all other decision components. Thus, selection of the preferred alternative is unlikely to change with a change or deletion of this performance measure.

Figure P-14 shows the radar diagram identifying the preferred alternative selected based upon the relative importance among the nine decision criteria established by the JLAs and Steering Committee (see Figure DSS-2). The preferred alternative, B-3, is highly ranked water quality, indian trust assets, cultural resources, and land use issues. It is the worst-ranked alternative for ecosystem needs, but was the top scoring ecosystem alternative of those alternatives maximizing upstream conservation storage potential. Alternative B-3 ranked low on the scales for sediment management and recreational uses. Per the weights established among competing criteria, alternative B-3 offers the best potential to manage the multiple objectives, multiple purposes, and competing goals for water management in the Upper Rio Grande.

Figure P-9. Preliminary Screening Results

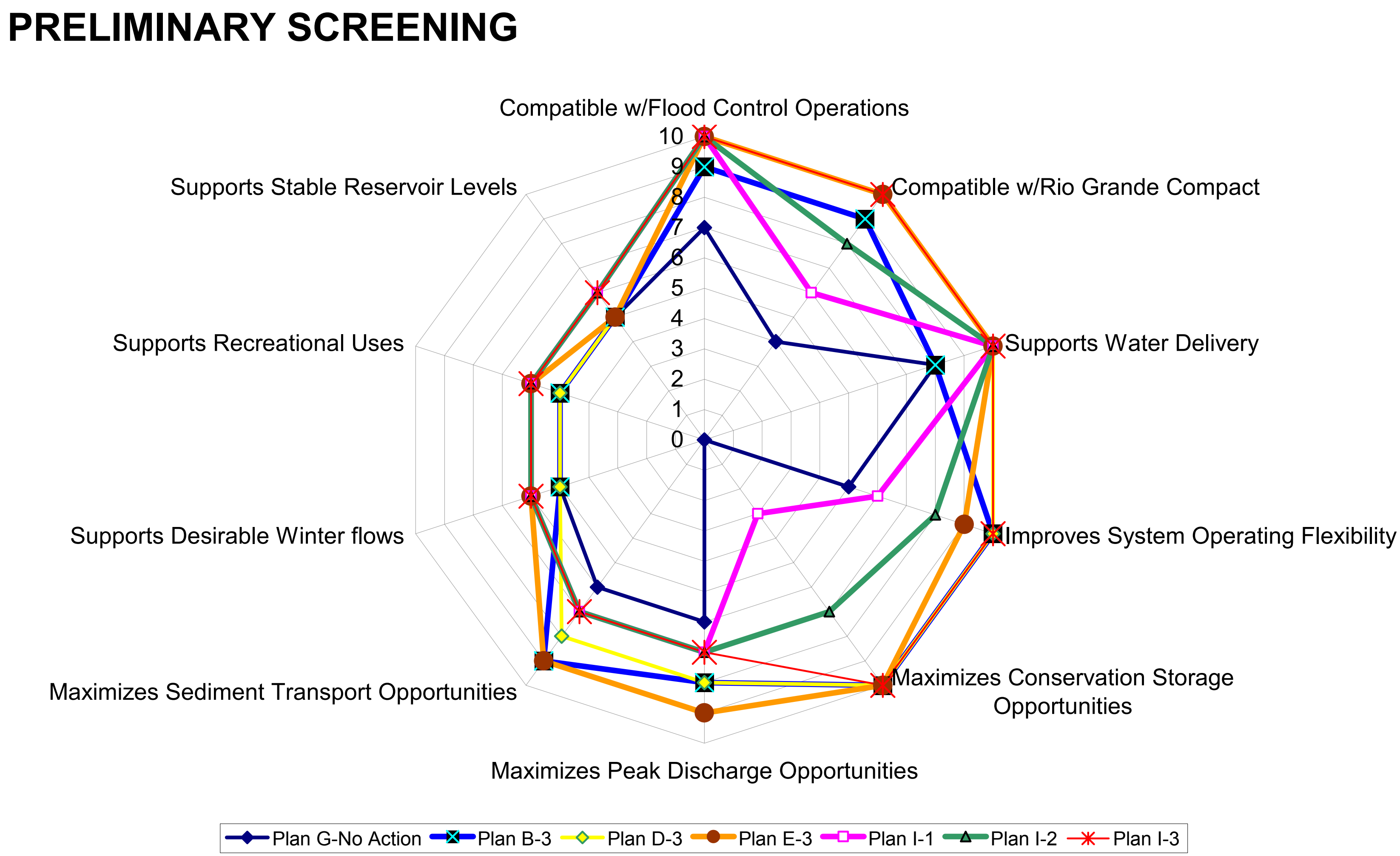


Figure P-10. Threshold Criteria

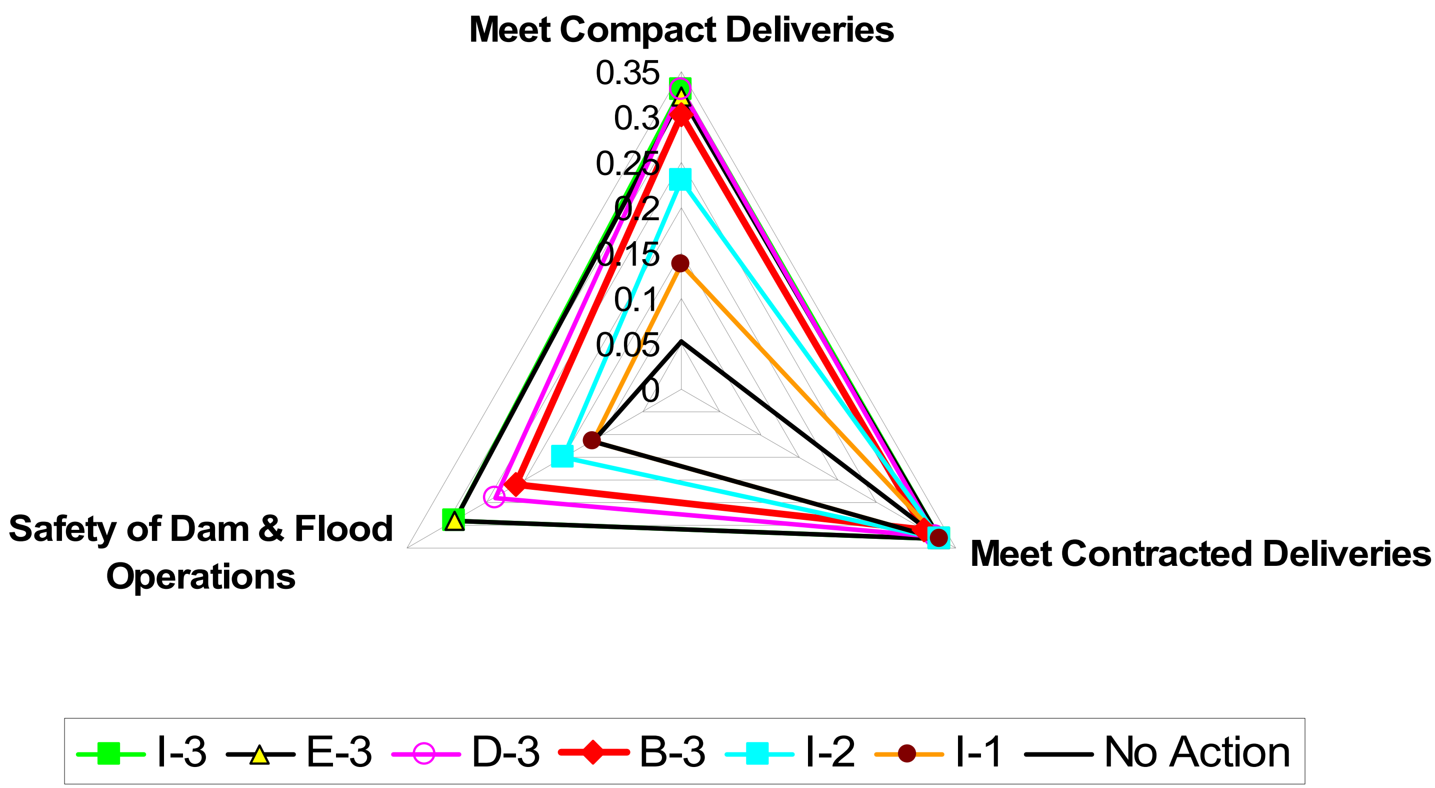


Figure P-11. Ecosystem Support

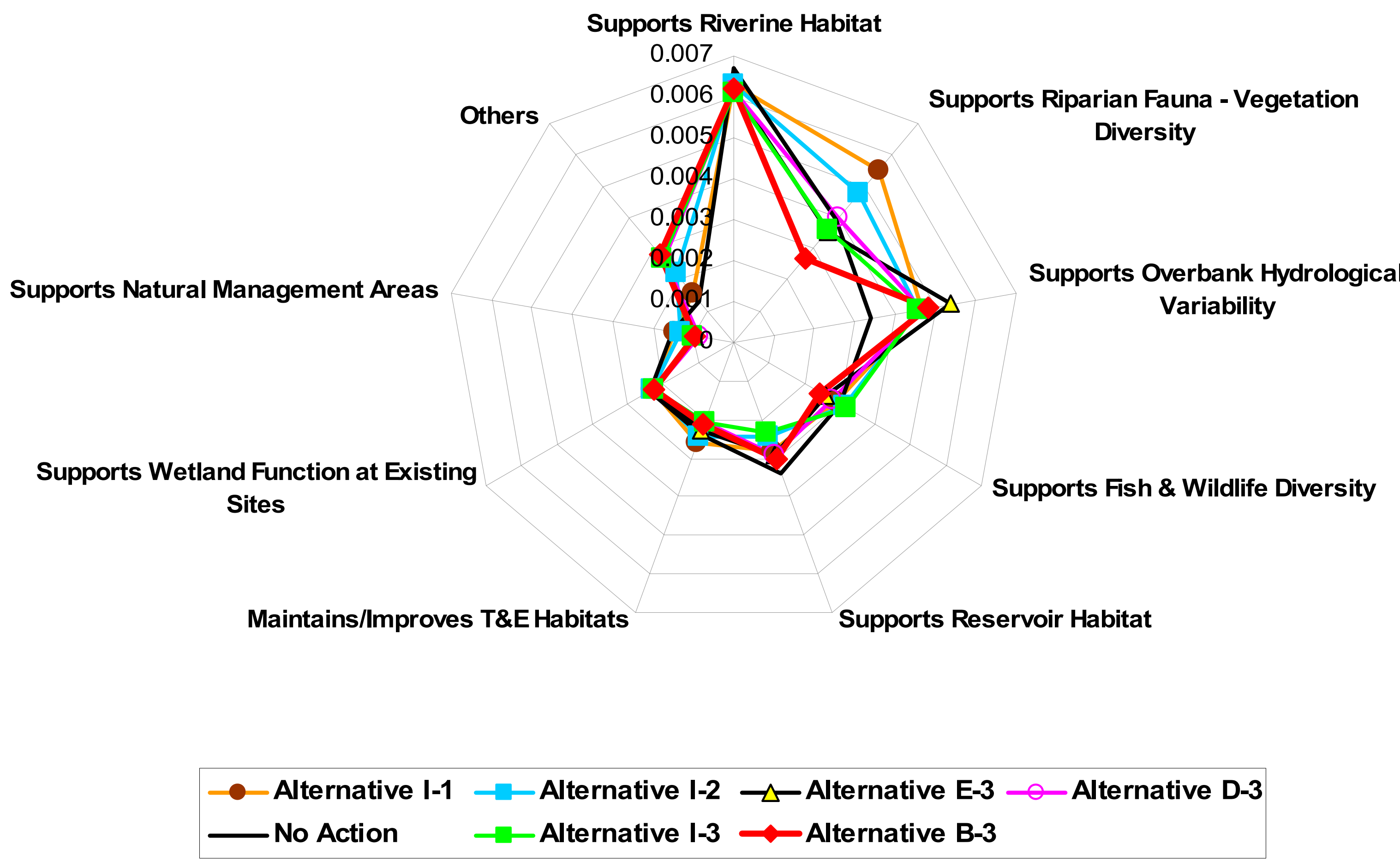


Figure P-12. Operating Flexibility

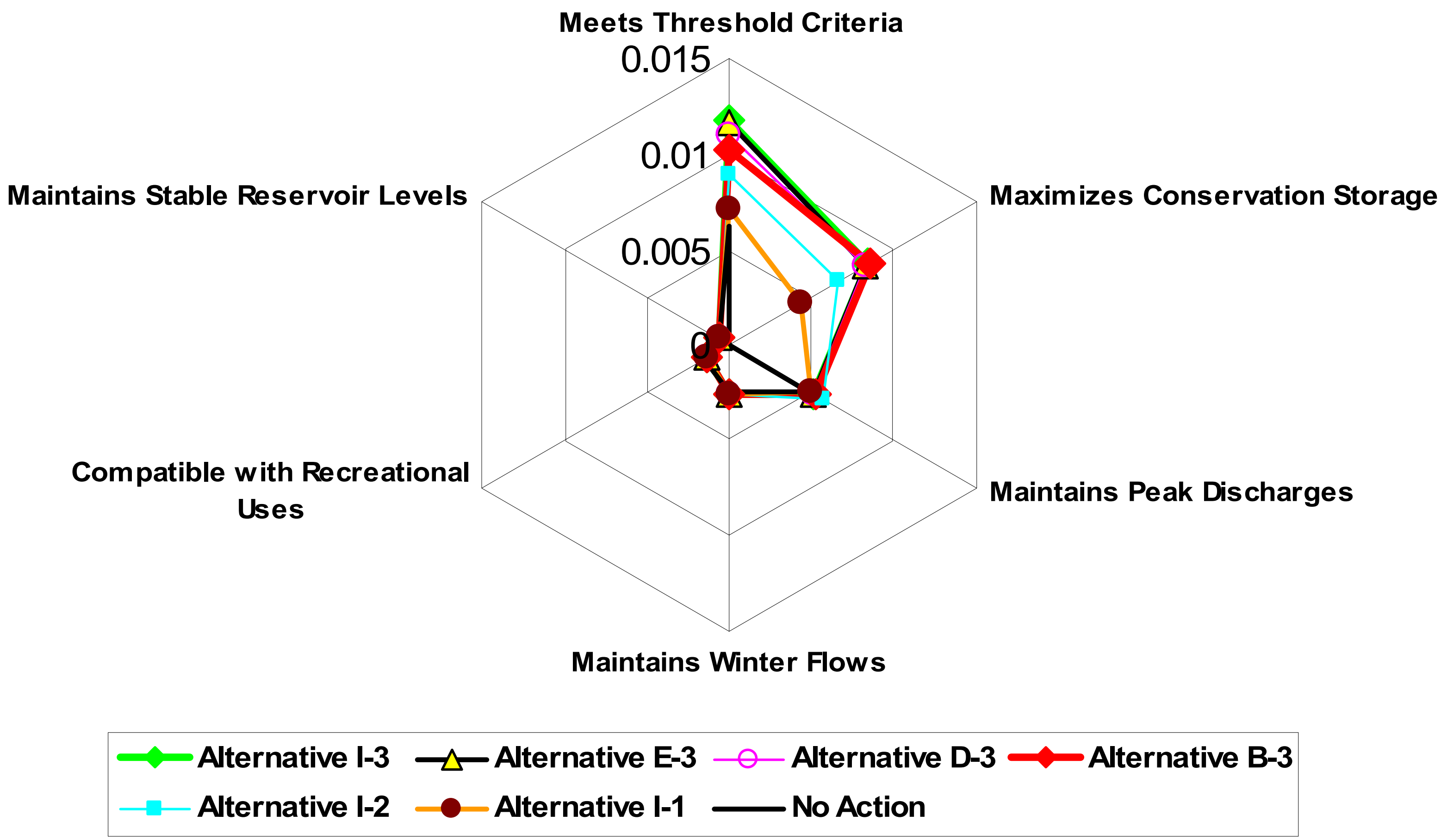


Figure P-13. Water Quality

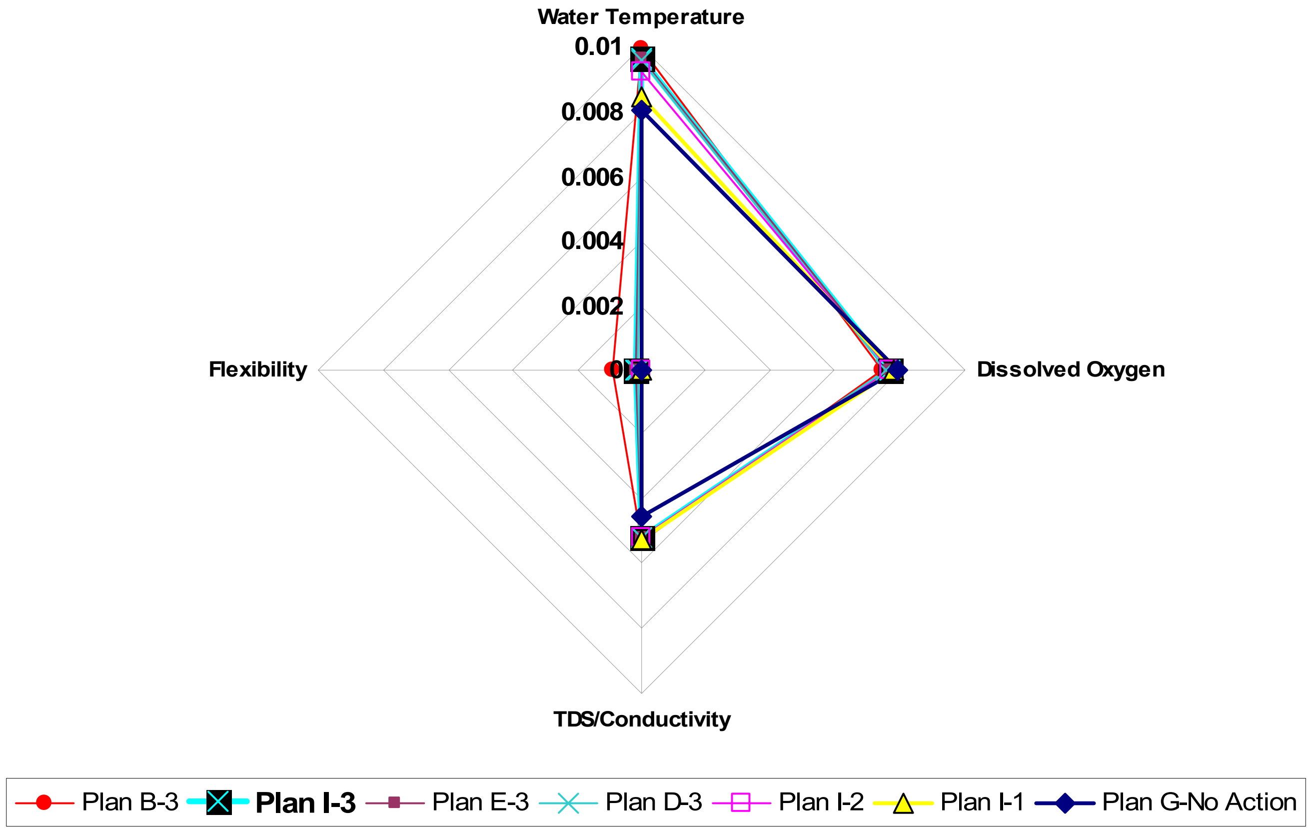
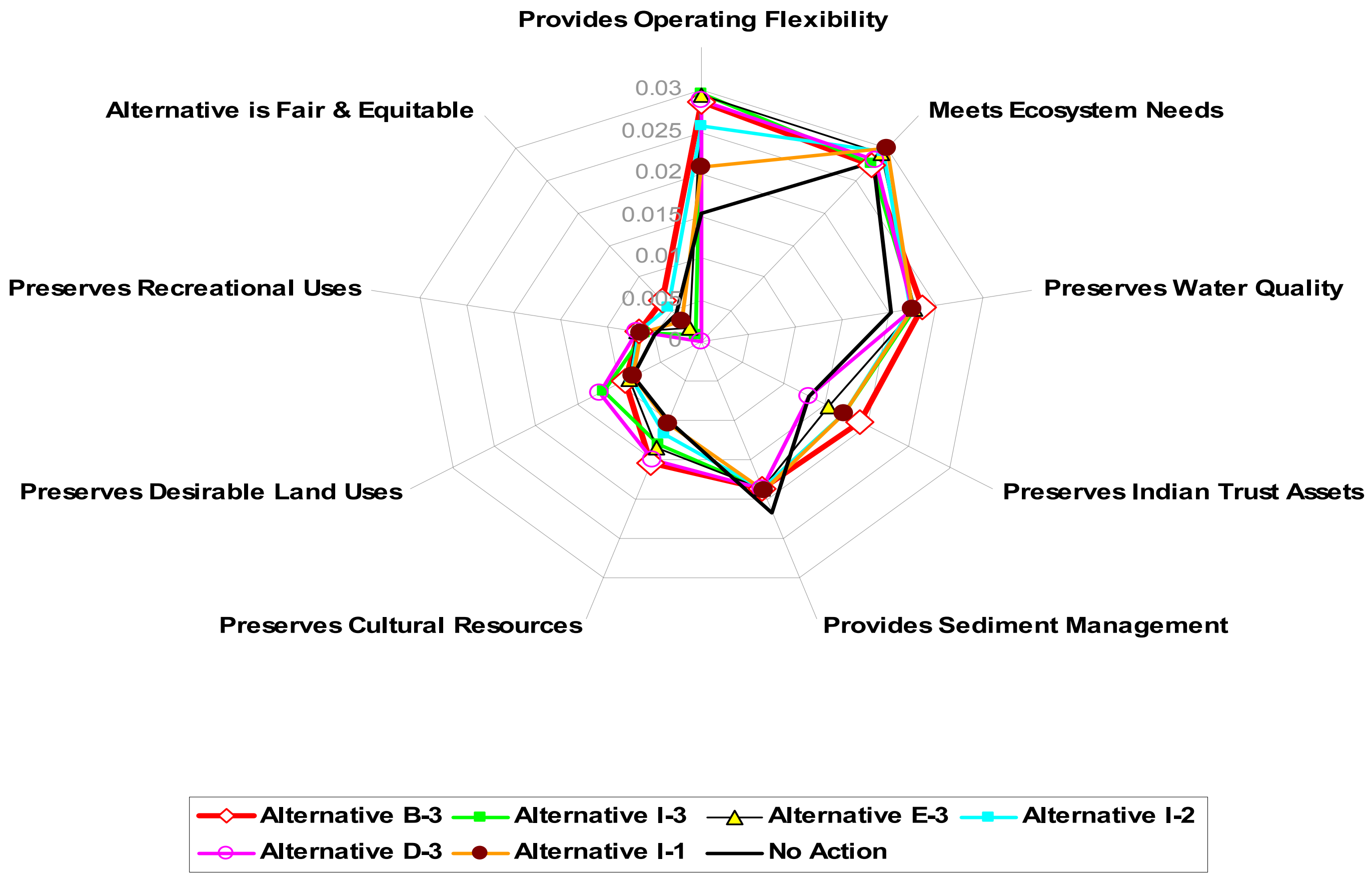


Figure P-14. Selecting the Preferred Alternative



1.6 Conclusions

As documented with CDP, Alternative B-3 was selected as the preferred alternative based on:

- Comparisons among available alternatives
- Decision criteria and weights
- Alternative performance on discrete performance measures
- Analysis of tradeoffs and uncertainties

This alternative presents the water operations plan that best satisfies the multiple objectives, multiple purposes, and diverse values represented among the agencies and stakeholders participating in this Review and EIS. It best supports and balances the multiple decision criteria identified for this Review and EIS. A bar chart showing the final ranking of alternatives is shown on **Figure P-15**.

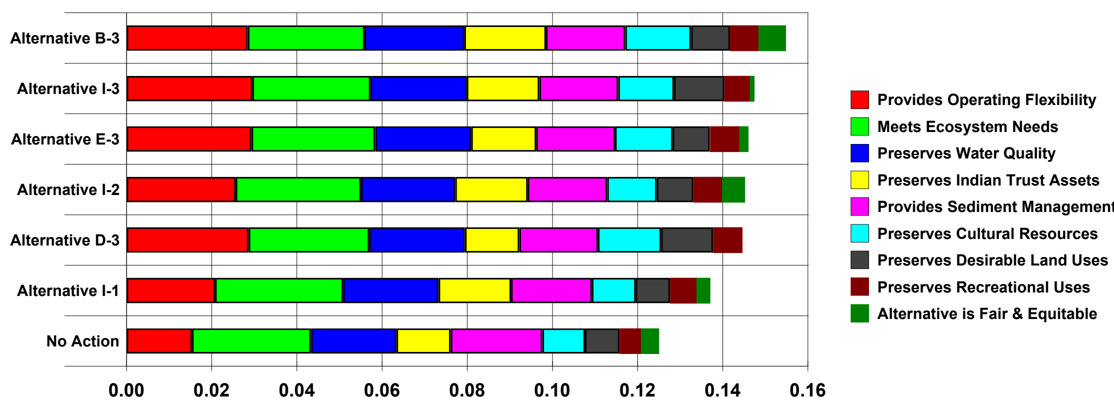


Figure P-15. Final Ranking of Alternatives

Alternative I-1 was identified as the environmentally preferred alternative based on rankings for the "Meets Ecosystem Needs" decision criterion. The environmentally-preferred alternative was not selected as the preferred alternative because it did not meet JLA threshold performance criteria for compact compliance.

The preferred alternative, Alternative B-3 is comprised of the following water operations elements:

Heron Reservoir Waivers: September 30
Abiquiu Conservation Storage: 0 – 180,000 AF
Abiquiu Channel Capacity: 1,500 cfs
Cochiti Channel Capacity: 8,500 cfs
Low Flow Conveyance Channel Operations: 0 – 2,000 cfs
Elephant Butte/Caballo Coordination: Improved Communication & Coordination
Improved Cooperation and Communications

2.0 Data Quality

2.1 Introduction

Members of the GIS Technical Team developed a database to enable all teams to document the datasets used in the EIS and to store information about the types of data, resolution, precision, accuracy, collection periods, and overall quality. In order to create this database, members of each technical team were required to enter known parameters of all datasets used in their respective analyses. In some cases specific parameters, such as accuracy and precision, could not be readily ascertained, and were not assigned. The intent of developing the data quality database was to disclose the quality of the datasets used in the evaluation of alternatives, determine areas where data are lacking, and to assist decision makers in understanding the comparison of alternatives in the context of data limitations. The database provides an evaluation of the assessment of impacts with respect to the overall quality and type of data used and available, independent of and complementary to the weighted decision criteria used in the decision support system.

2.2 Content of Data Quality Database

Essentially, the data quality database is a coarsely standardized and cataloged list of datasets specific to each resource team and their evaluation of the EIS alternatives. Technical experts of each team, considered the known parameters (i.e. spatial extent, accuracy, precision, resolution, collection period and method, etc.) of each dataset together with their professional opinion, in order to rate each dataset discretely as good, fair, or poor. Because the data quality rating was assigned based on a dataset's applicability and usefulness for this Review and EIS, a rating of fair or poor may only apply in the context of this analysis and may not reflect negatively on the source of the data. For example, some of the economic data, although accurate and correct, could only be applied at the county level, so it may have been rated as fair because the resolution was not ideal for this analysis, in spite of its high quality and confidence level for other uses. Although somewhat simplistic, these rating designations allow for a direct quality comparison of largely non-comparable data. Often, error estimation or confidence intervals (e.g. ± some value) were not available because the source did not provide such descriptive statistics, the raw data was not available, or it was qualitative. In such cases, the rating of that particular dataset relied on the team's relative confidence in the data and its applicability for evaluation of impacts under each alternative.

The dataset's ratings and descriptors were compiled and entered into a Microsoft Access™ database, allowing for queries to be formulated to selectively evaluate the quantity, quality, and other attributes of the data, grouped by subreach, reach, or river section to provide a spatial component. Descriptive fields in the database include, but are not limited to: source of the data, accuracy, precision, spatial resolution, method and date of collection, collection interval, and a general notes fields.

2.3 Use of Data Quality Information as Applied to the Review and EIS; Identification of Data Gaps

Data quality has an explicit and dependent relationship with the effects analyses under all alternatives. In other words, the quality and applicability of the data used to evaluate the performance of the alternatives directly affects the relative assessment of impacts to each resource. Hypothetically, if impacts were determined to be beneficial to a resource based on insufficient or inadequate data, then the decision makers may unwittingly make judgments supported by flawed conclusions. The data quality evaluation process and database were developed to facilitate understanding of such a complex and multivariate analysis as this Review and EIS in a comprehensive manner.

The data quality analysis has two principal goals:

1. To disclose the quantity and quality of data used in each resource analysis and consider the interaction of data quality with the hierarchy of decision criteria used in the decision support system. Thus, a more informed judgment can be rendered on the predicted impacts of a given alternative and why, potentially, that alternative may be more or less desirable.
2. To clearly identify data gaps by resource area so that future actions and analyses can plan for data collection to improve quality or spatial distribution as needed. This may apply to adaptive management monitoring, planning, and implementation, as well as for future modeling and NEPA analyses..

2.4 Underlying Model Data Quality

2.4.1 URGWOM

In this Review and EIS, URGWOM provides the necessary modeled flows over the 40-year sequence that was used either the sole basis for alternative evaluation (such as fishing and rafting flows, reservoir turnover rate, etc.) or as input to additional models (FLO-2D and Aquatic Habitat Model). As such, URGWOM data quality and reliability is central to all aspects of the analysis and efforts to quantify the performance of URGWOM focused on the ability to replicate historical hydrology (Thomas 2002; Wilkinson 2003).

Figure P-16 displays the estimated number and quality of URGWOM datasets that were utilized in the effects analyses for this Review and EIS. Although URGWOM performance is generally considered robust, Figure DQ-1 clearly shows a trend of decreasing data quality in a north-to-south direction. The reasons for this are varied and remain largely undefined, although some relate to the accuracy of gage data. Enhancements and improvements to URGWOM implemented in the future are likely to improve data quality so that it more closely matches historic flows.

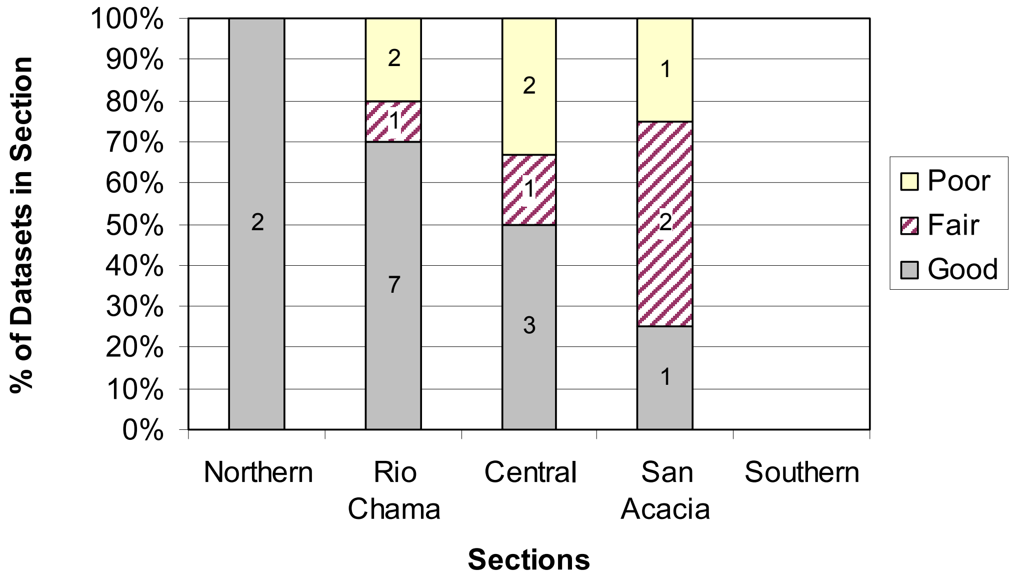


Figure P-16. URGWOM Data Quality

2.4.2 FLO-2D

In order to predict the extent and effect of overbank flows, this Review and EIS utilizes FLO-2D; a two-dimensional hydrology and hydraulics model (see Section 2.2.4 and Appendix J). FLO-2D uses URGWOM Planning Model predictive hydrology as input and numerically routes and attenuates flood flows spatially through a grid system within the channel and over the floodplain. The output from FLO-2D provides water depth and velocity in each grid cell. FLO-2D output data were used in the evaluation of the alternatives in terms of their impacts on riparian and wetland resources, as overbank flooding is an important factor in the sustainability of the riparian ecosystem. Other analyses based on FLO-2D output includes the Aquatic Habitat Model, flooding of recorded archaeological sites, frequency of overtopping of diversion dams for irrigation, and inundation of different land uses, especially agricultural land.

Figure P-17 shows decreasing data quality from north-to-south. The reasons for this are a general lack of high resolution topographic relief data and active river channel cross-section survey data. Grid cell size utilized in modeling the lower Rio Chama was smaller than that applied in the Rio Grande reaches, improving spatial resolution and resulting in better quality model output. FLO-2D utilizes URGWOM data, which also shows this pattern of decreasing data quality from north to south. FLO-2D was not used to model the Northern and Southern Sections.

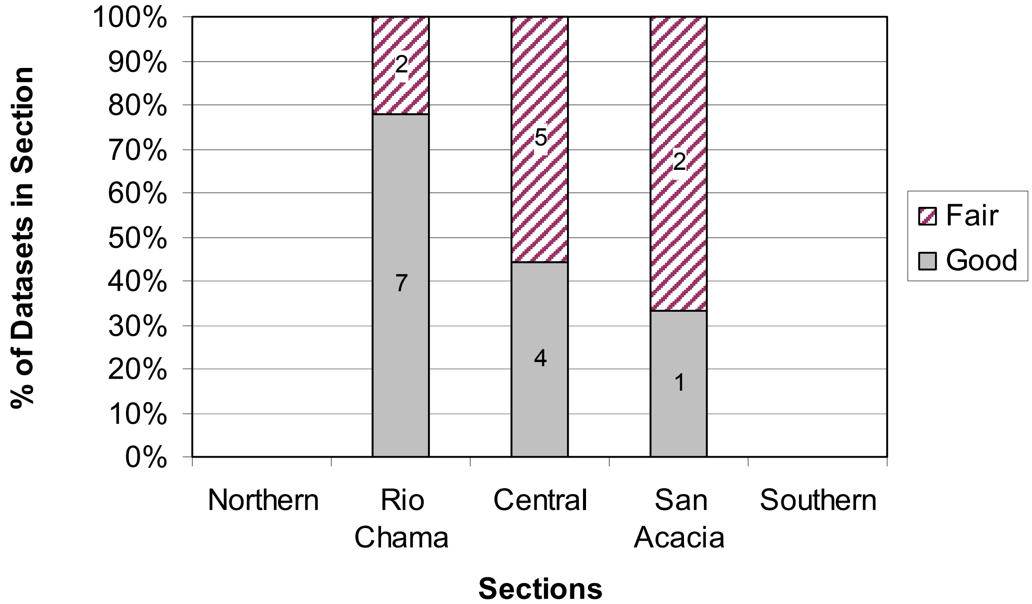


Figure P-17. FLO-2D Data Quality

2.5 Data Quality by Decision Criterion

The decision criteria developed for the decision support system provides a hierarchical framework in which to evaluate the overall and resource-specific data quality. Considering data quality according to the decision criteria hierarchy allows for evaluation of data quality according to the relative importance of the resources affected by water operations, without applying an additional layer of weighting or assuming that all resource datasets are of equal importance for alternatives analysis. Given the crucial role of URGWOM and FLO-2D model output in the analysis of impacts for many decision criteria, the resource-specific data are presented with the relevant URGWOM and FLO-2D data where appropriate. This accounts for the influence of URGWOM and FLO-2D data in conjunction with the resource-specific data.

In the following sub-sections, data quality is presented under each decision criterion, and each decision criterion is listed in order of importance (highest to lowest) based on the weights assigned in the decision support system, grouped by river section from north to south.

Specific information regarding the use, analysis, and conclusions for each of the following resource categories can be found in Chapter 4 and their appropriate appendices.

2.5.1 Meets Ecosystem Needs

The Riparian and Wetlands and Aquatic Systems Technical Teams analyzed how well each alternative met this decision criterion. These teams evaluated the alternatives in terms of the effects of proposed water operations on key habitat and wildlife species including threatened and endangered species. Analyses considered fish and fish habitat, riparian vegetation and wetlands, and potential impacts to specific terrestrial wildlife. The effects analyses for this decision criterion recognize the interrelated nature of the aquatic and terrestrial systems under an ecosystem approach.

Figure P-18 suggests that the effects analyses and conclusions are supported by generally good data. The lowest quality is in the Southern Section where slightly fewer than 50 percent of the datasets is fair and the remainder is good. In all other sections, at least 60 percent is good. In the San Acacia Section, which was identified as the most important reach for evaluating impacts to ecosystems, the overall number of datasets used was the least of the three sections most affected by proposed water operations. Only small proportions in the Rio Chama, Central, and San Acacia sections are classed as poor.

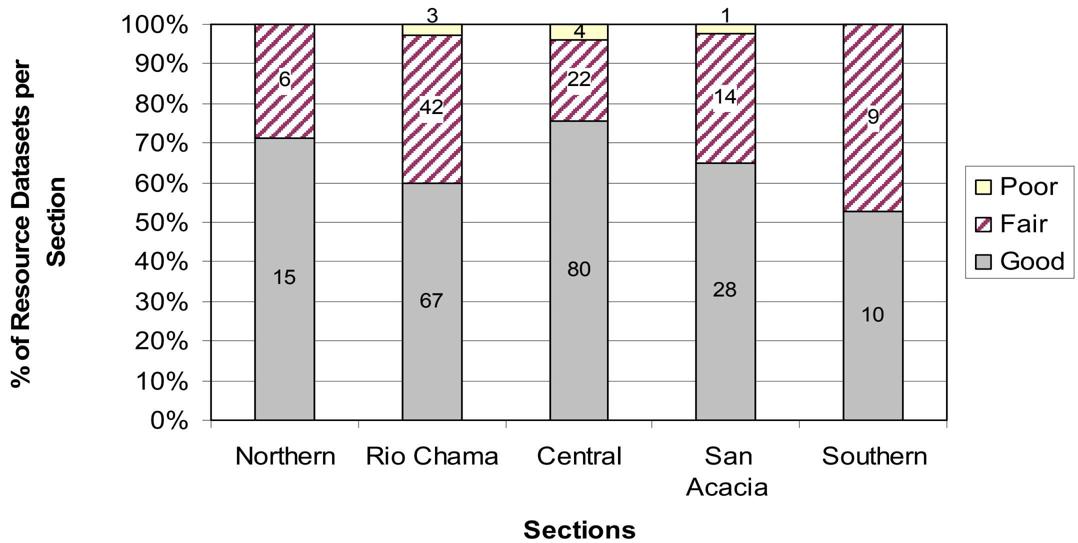


Figure P-18. Data Quality for "Meets Ecosystem Needs" Decision Criterion (Includes URGWOM and FLO-2D Datasets)

2.5.2 System Operating Flexibility

The Water Operations/URGWOM Integration Technical Team addressed how each alternative affected flexibility for water operations management. System operating flexibility includes maximizing conservation storage, maintaining discharges from reservoirs, maintaining winter flows, compatibility with recreational uses, and maintaining stable reservoir levels. Water managers would have varying degrees of operational latitude under each alternative, which is scored in terms of how well it meets the above metrics. URGWOM data quality is presented in Section 1.1.4.1, where it is characterized as generally good.

2.5.3 Preserves Water Quality

The analyses for this criterion were completed by the Water Quality Technical Team, and used URGWOM hydrology correlated with water quality behavior under each alternative. Metrics for the water quality analysis are dissolved oxygen, temperature, and total dissolved solids/conductivity.

Figure P-19 indicates that water quality data, in all but the Northern section, is at least 50 percent fair or poor. These data may be more robust than the rating suggests, but their applicability is not entirely suitable for this analysis, due in part to the year collected, discontinuity, and limited geographic scope. Water quality data is subject to a high degree of variability over space and time, so many more datasets would be needed to evaluate changes within the vast geographic area of the river sections, before data quality could be rated predominantly good for this type of analysis. Due to the high proportion of poor and fair datasets, the impact evaluations should be considered somewhat problematic on an absolute basis. However, because all alternatives were evaluated using the same data, the comparison of impacts across alternatives would apply the same error on a relative basis and would not adversely affect the conclusions.

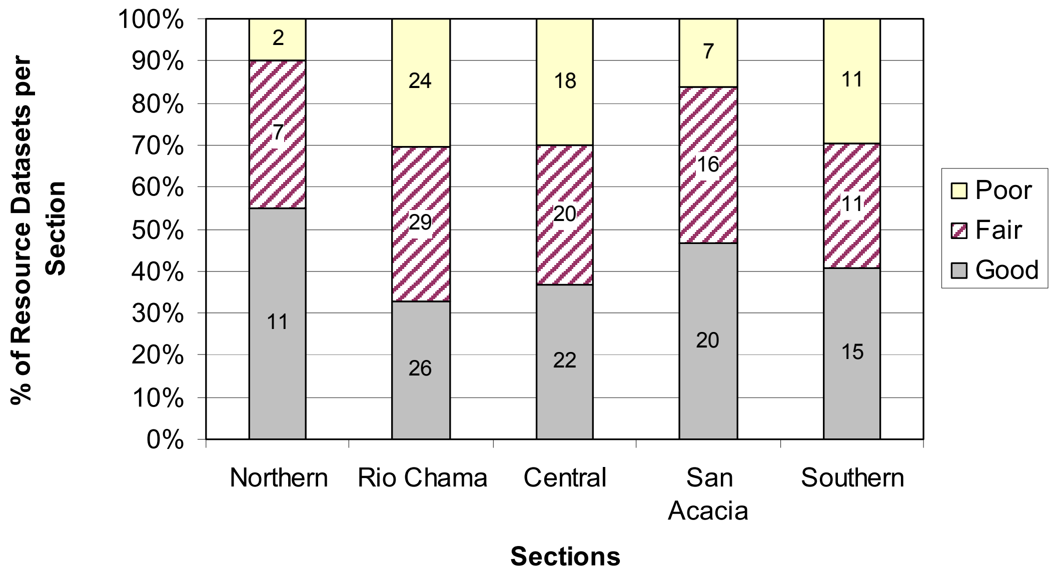


Figure P-19. Data Quality for "Preserves Water Quality" Decision Criterion Impact Analysis (Including URGWOM Datasets)

2.5.4 Provides Sediment Management

This criterion was addressed by the River Geomorphology, Sedimentation, and Mechanics Technical Team. The analysis evaluated the overall transport and management of sediment and how each alternative performs to improve sediment transport, create favorable aggradation/degradation trends, create favorable bank energy index, and increase sediment volume.

Figure P-20 suggests that the best data quality is in the Northern and Rio Chama Sections, with a higher proportion of fair and poor quality datasets in the Central and San Acacia Sections. The data in these downstream sections may be rated lower because most were not collected specifically for this Review and EIS. The Southern Section was not addressed due to limitations imposed by the JLA and the fact that no changes were anticipated as a result of proposed water operations.

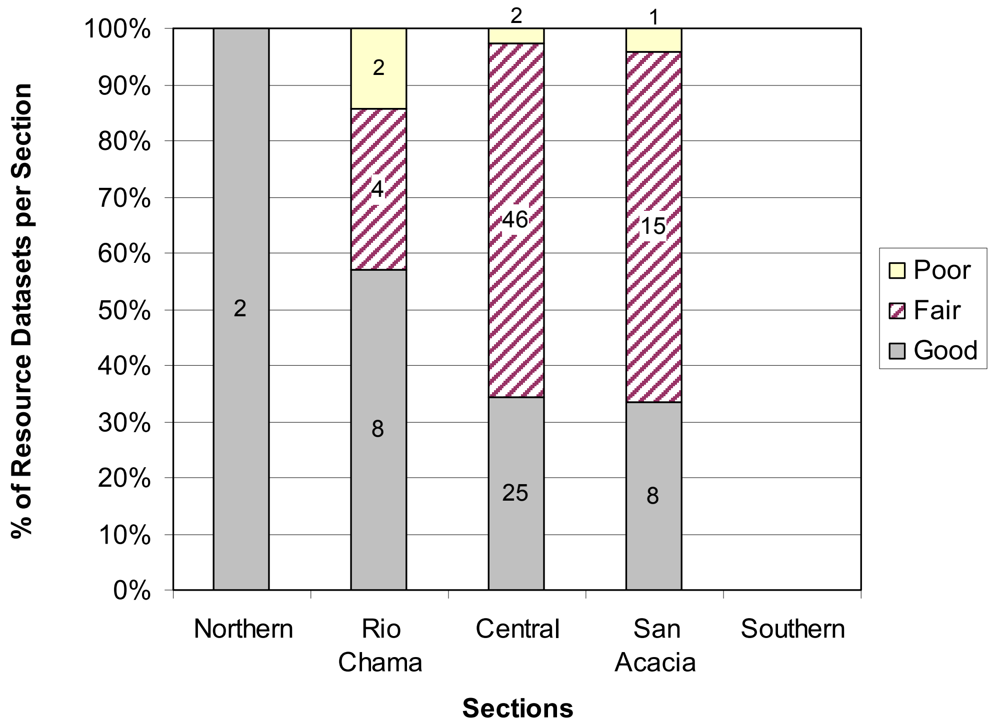


Figure P-20. Data Quality for "Provides Sediment Management" Decision Criterion Impact Analysis (Including URGWOM Datasets)

2.5.5 Preserves Indian Trust Assets and Cultural Resources

The Cultural Resources Technical Team was responsible for most of the data collection and analysis. Additional information provided through government-to-government consultations is being collected and will continue to be considered throughout the EIS process. However, the information collected through consultation may not be suitable or appropriate to evaluate for data quality using this process.

The analysis evaluated the impacts of implementing the alternatives upon known cultural resources, such as acequias and traditional cultural properties, and archaeological sites. For example, if a recorded archaeological site would be affected by overbank flooding under a certain alternative, that condition was counted as an adverse impact to cultural resources.

Figure P-21 indicates a high proportion of fair and poor quality datasets used in the effects analysis. The Central and San Acacia Sections contain the greatest proportion of fair datasets. The relatively low quality data can be attributed, in large part, to the fact that the density of recorded cultural resources, especially archaeological sites, is low. Surveys and documentation of cultural resources occurs primarily on state and federal lands along the river corridor, and the poor and fair ratings acknowledge the likelihood that there are many unreported sites that could not be included in the effects analyses. Impact analysis could be improved if additional surveys and site documentation were completed, especially in areas where flooding is projected.

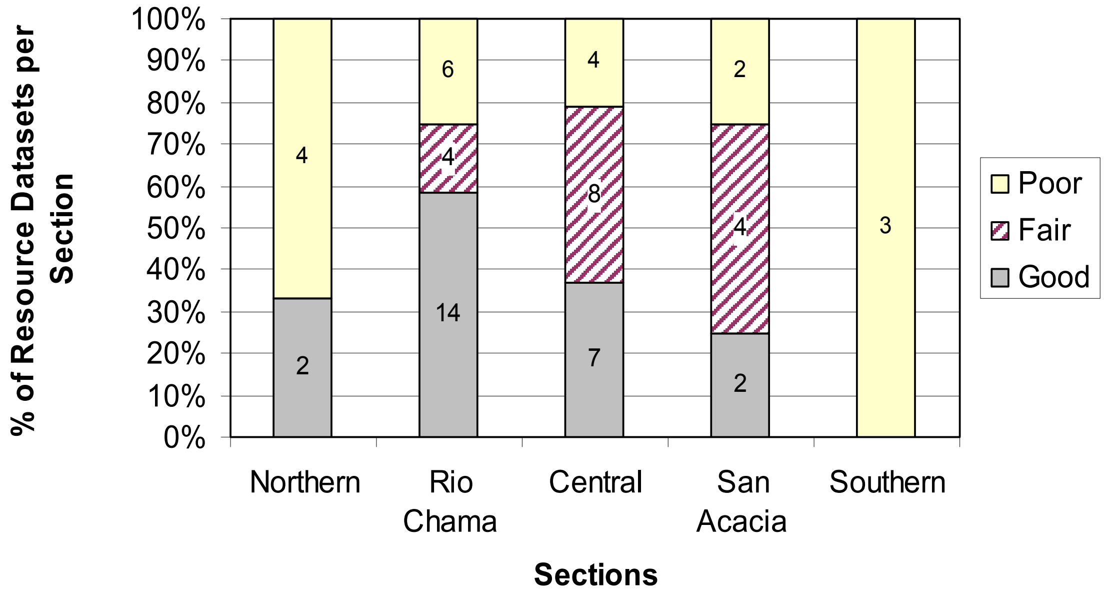


Figure P-21. Decision Criterion "Preserves Indian Trust Assets and Cultural Resources" Data Quality Impacts Analysis (Including URGWOM and FLO-2D Datasets)

2.5.6 Preserves Desirable Land Uses

This criterion was addressed by members of the Land Use, Recreation, Agriculture, Socioeconomics, and Environmental Justice Technical Team. The analysis evaluates the impacts of the alternatives upon existing land uses, with a focus on agriculture. The metrics evaluated include overtopping of irrigation structures, frequency and duration of periods in which irrigation delivery would not be met, inundation of agricultural lands, and suitability for existing, protected, and special uses.

Figure P-22 demonstrates that most of the data used for this analysis was of fair quality. This is primarily due to the lack of quantitative and spatial data for agricultural land that is comparable from section to section. It also reflects the relatively coarse resolution for evaluating factors such as the frequency of overtopping diversion dams annually that may result from water operations management.

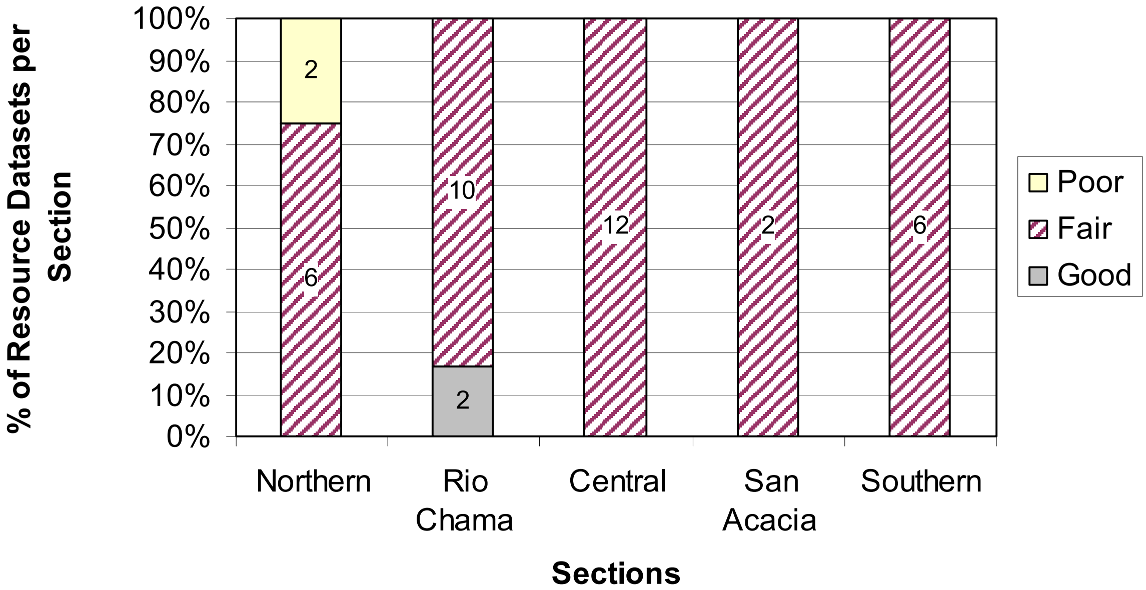


Figure P-22. Data Quality for "Preserves Desirable Land Uses" Decision Criterion Impacts Analysis (Including URGWOM and FLO-2D datasets)

2.5.7 Preserves Recreation Uses

This criterion was addressed by members of the Land Use, Recreation, Agriculture, Socioeconomics, and Environmental Justice. The analysis considers the alternative impacts on reservoir and riverine economics, visitation, as well as the frequency of conditions suitable for recreational opportunities like rafting boating, and fishing.

Figure P-23 displays the predominance of fair quality datasets for this analysis. The lack of good quality datasets reflects the relatively coarse resolution and qualitative nature of much of the information used for effects analysis.

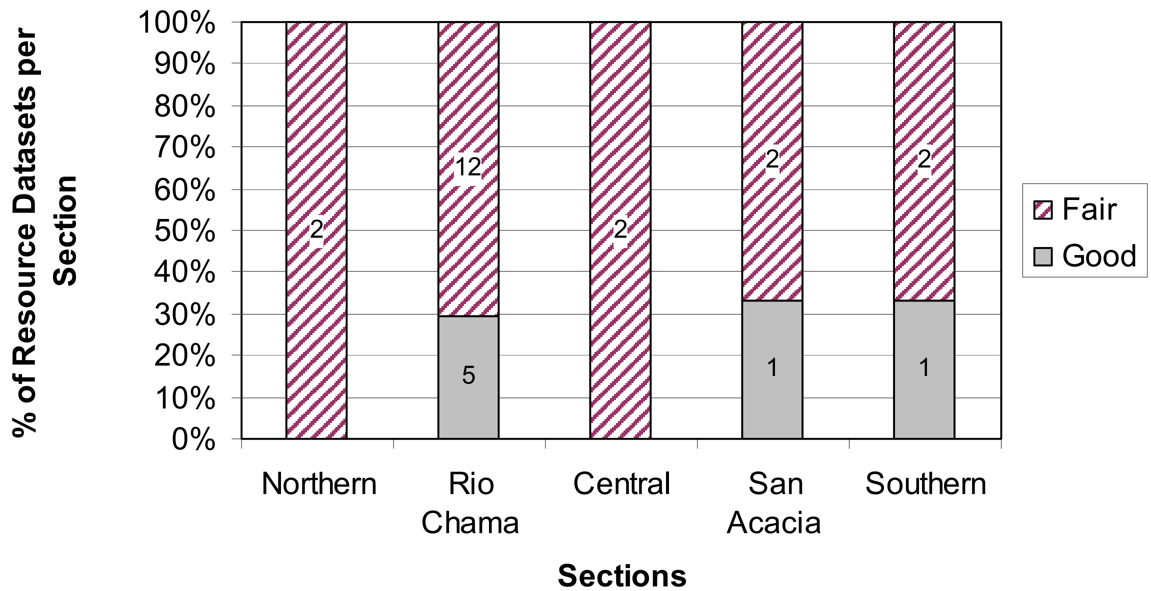


Figure P-23. Data Quality for "Preserves Recreational Uses" Decision Criterion Impacts Analysis (Including URGWOM and FLO-2D datasets)

2.5.8 Alternative Is Fair and Equitable

This criterion was addressed by members of the Land Use, Recreation, Agriculture, Socioeconomics, and Environmental Justice and is often referred to as environmental justice. Analysis of environmental justice addresses whether there are impacts under any alternative that disproportionately affect minority or low-income populations.

Figure P-24 shows that all datasets were rated fair as applied to the effects analysis under each alternative. The information was derived from Census data, which is generally of good quality. However, this rating was given primarily because the data was applied at the county or municipal level rather than scaled to populations in the river corridor.

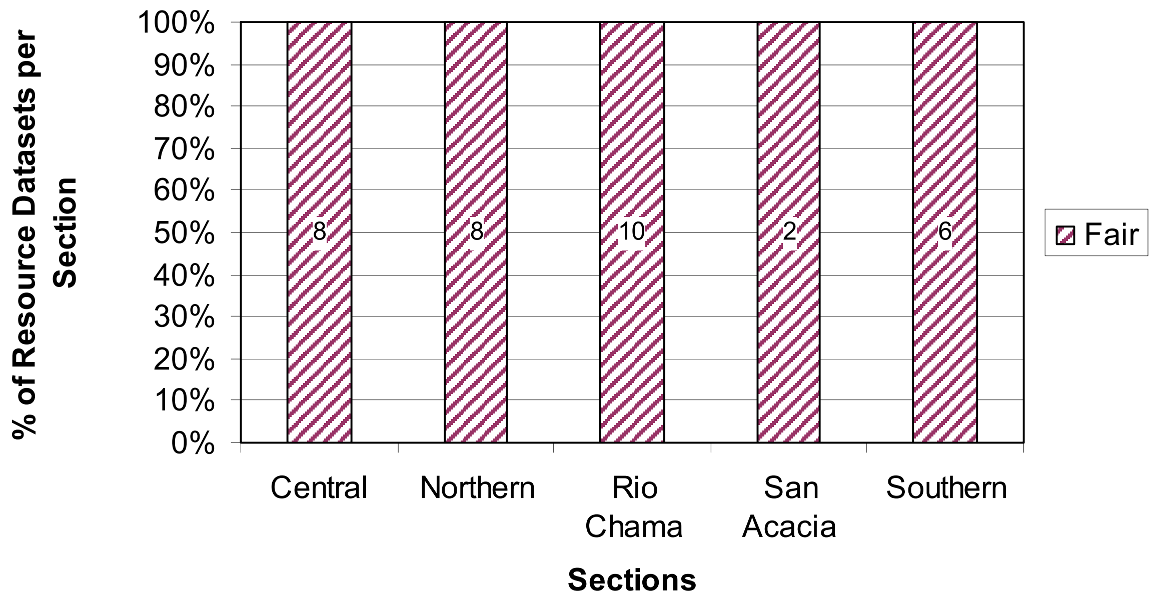


Figure P-24. Data Quality for "Alternative is Fair and Equitable" Decision Criterion Impacts Analysis

2.6 Data Gaps by Technical Team

Data gaps may be identified through documenting poor quality datasets or by determining missing data that would be useful for future analyses. As technical teams collected data for this Review and EIS, they often found that large quantities of data were available for specific reaches or sections, while other parts of the river corridor have not been studied as well and were lacking in available research and information. The differences in numbers of datasets, in addition to the varying proportions of good, fair, and poor datasets, can be seen in all of the following charts.

To disclose data gaps for future work, the following sections summarize the quality and number of datasets used by each technical team, independent of the URGWOM and FLO-2D model output used for analysis. Some suggestions related to the reasons for the gaps are included, but they are not comprehensive.

2.6.1 Water Operations/URGWOM Integration Technical Team

The decreasing quality of URGWOM data from north to south constitutes a significant data gap that could be improved through refinements and enhancements of the model, as well as more accurate gage data. Future model enhancements are planned for URGWOM, including improved methods of calculating river channel leakage rates, agricultural and riparian evapotranspiration rates, ungaged tributary and local inflows, MRGCD diversion volumes and return flows, and irrigation deep percolation rates (Thomas 2002). The Southern Section was not modeled for this Review and EIS, but efforts at coordinated data collection for future modeling is underway. Figure DQ-1 displays URGWOM data quality and quantity as evaluated for this EIS.

2.6.2 Hydrology and Hydraulics Technical Team

Improvements to URGWOM should also improve FLO-2D performance. The Northern and Southern Sections were not modeled mainly because no changes to flows were anticipated in these sections as a result of water operations considered under any alternative. Other hydrology and hydraulics datasets were not evaluated for this effort, so the data quality used by this team is displayed in Figure DQ-2.

2.6.3 Aquatic Systems Technical Team

Figure P-25 shows that URGWOM data did not have much influence on the data quality used by this team. However, the aquatic habitat data appears to influence the ecosystem decision criteria, as aquatic data trend closely tracks the ecosystem criteria trend shown in Figure DQ-3. Aquatic habitat data quality would be improved if additional studies and model sites were developed to evaluate aquatic habitat for fish species, especially in the Northern and Southern Sections. Currently, Aquatic Habitat Model output has limited application beyond the study sites evaluated, so habitat cannot be assessed for entire reaches or sections.

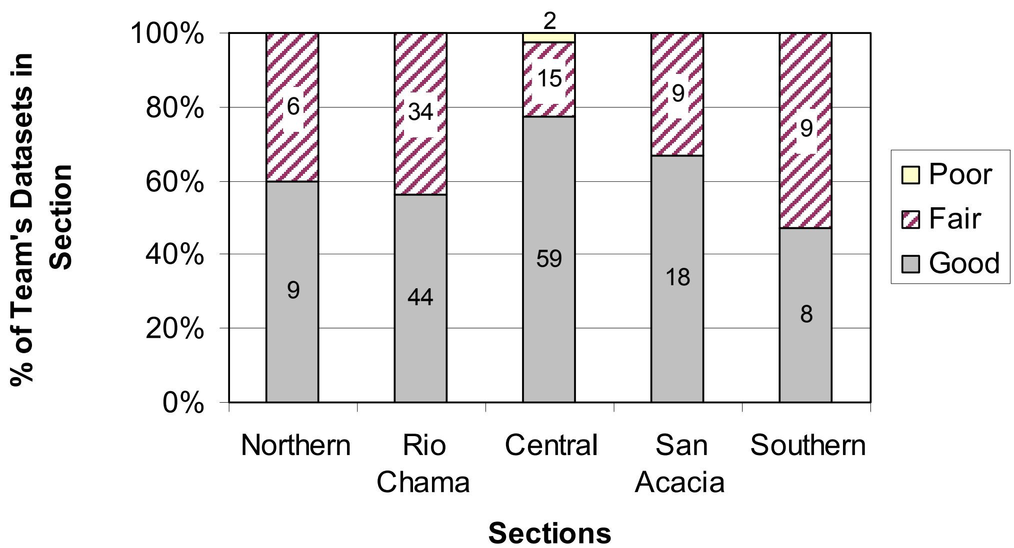


Figure P-25. Aquatic Systems Data Quality Gaps (Excluding URGWOM and FLO-2D Datasets)

2.6.4 Riparian and Wetlands Technical Team

Figure P-26 demonstrates that the information collected and used by the Riparian and Wetlands Technical Team is dominated by good and fair quality datasets. This reflects, in part, the vegetation mapping performed for this Review and EIS. Additional information is needed to characterize the Northern and Southern Sections.

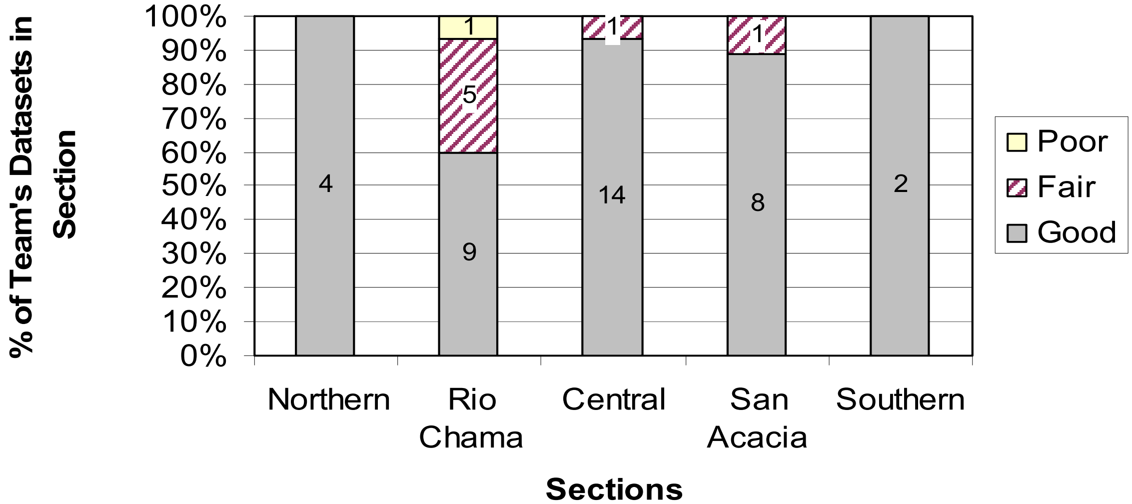


Figure P-26. Riparian and Wetlands Data Gap Analysis (Excluding URGWOM and FLO-2D Datasets)

2.6.5 Water Quality Technical Team

Figure P-27 shows that no section exceeds 50 percent good quality. Filling in data gaps should be considered a priority for future actions, a fact recognized by improvements in water quality data collection that are underway. As part of the ongoing development of URGWOM, a continuous monitoring network in the Central Section has been initiated, in cooperation with the FWS and the University of New Mexico. In addition, monthly longitudinal sampling and synoptic surveys are currently being conducted for nutrients and other water quality constituents. These data will require two or three years before proving useful in an assessment or predictive manner, but can be used eventually to model water quality in URGWOM.

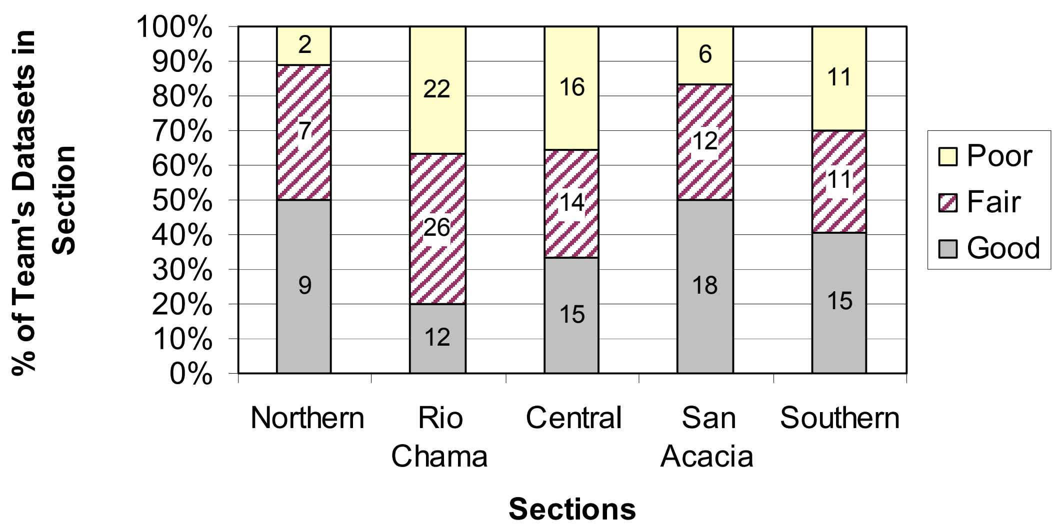


Figure P-27. Water Quality Data Gap Analysis (Excluding URGWOM Datasets)

2.6.6 River Geomorphology, Sedimentation, and Mechanics Technical Team

Figure P-28 shows significant data gaps although there are no poor quality datasets. Because no data were collected or used by this team for the Northern and Southern Sections for this EIS, none are shown in the graph. This only means that they are not part of the data quality evaluation for this Review and EIS, and may not reflect the current state of data in these regions. Due to the low numbers in the Rio Chama Section and the high proportions of fair quality data, data gaps should be considered prominent in all sections.

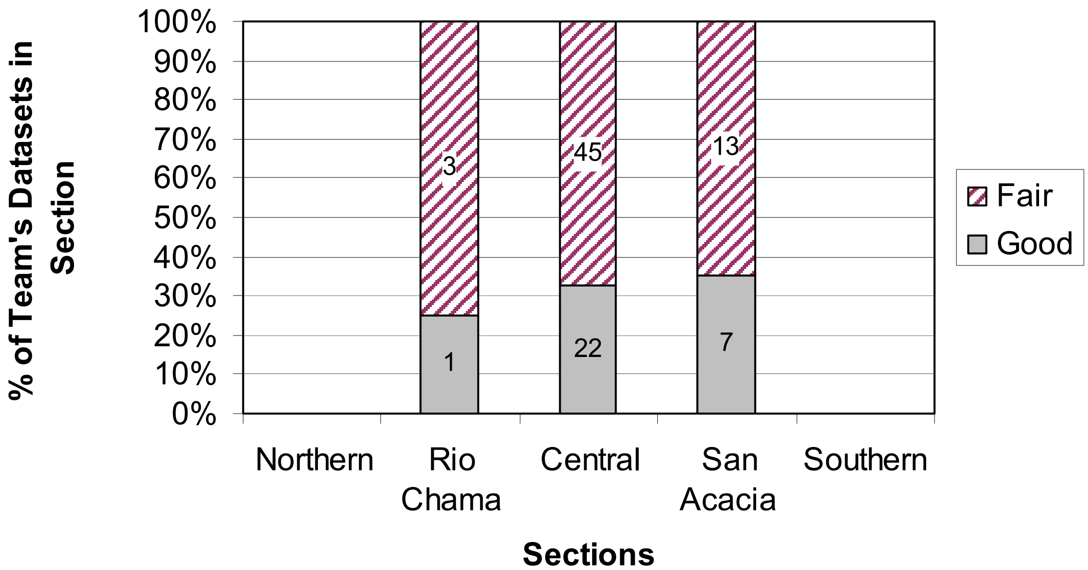


Figure P-28. Geomorphology, Sedimentation, and Mechanics Data Gap Analysis (Excluding URGWOM Datasets)

2.6.7 Cultural Resources Technical Team

Figure P-29 strongly suggests noteworthy data gaps. The Central and Rio Chama Sections have the highest number of fair datasets, but all sections contain a major proportion of poor quality data and low total numbers of datasets. This is due mainly to the low density of archaeological surveys along the river corridor, as well as the lack of site-specific information about traditional cultural properties. Data gaps are widespread and significant.

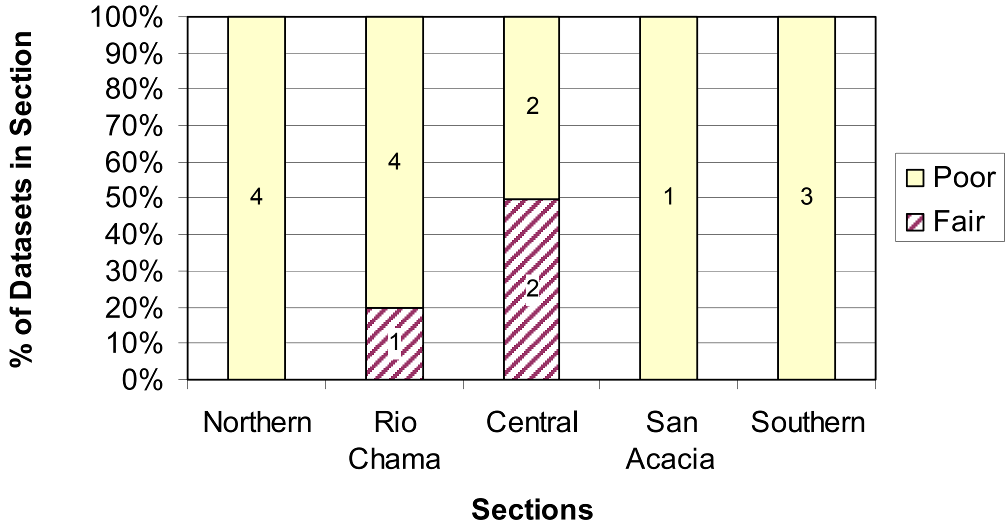


Figure P-29. Cultural Resources and Indian Trust Assets Data Quality Distribution – Impacts Analysis (not including appropriate URGWOM and FLO-2D datasets)

2.6.8 Land Use, Recreational Use, Socioeconomics, and Environmental Justice Technical Team

This technical resource team evaluated the alternative impacts for land use, recreation, agriculture, socioeconomics and environmental justice. **Figure P-30** shows that all sections are dominated by fair data quality. For data gap analysis, all data used by the technical team are considered together.

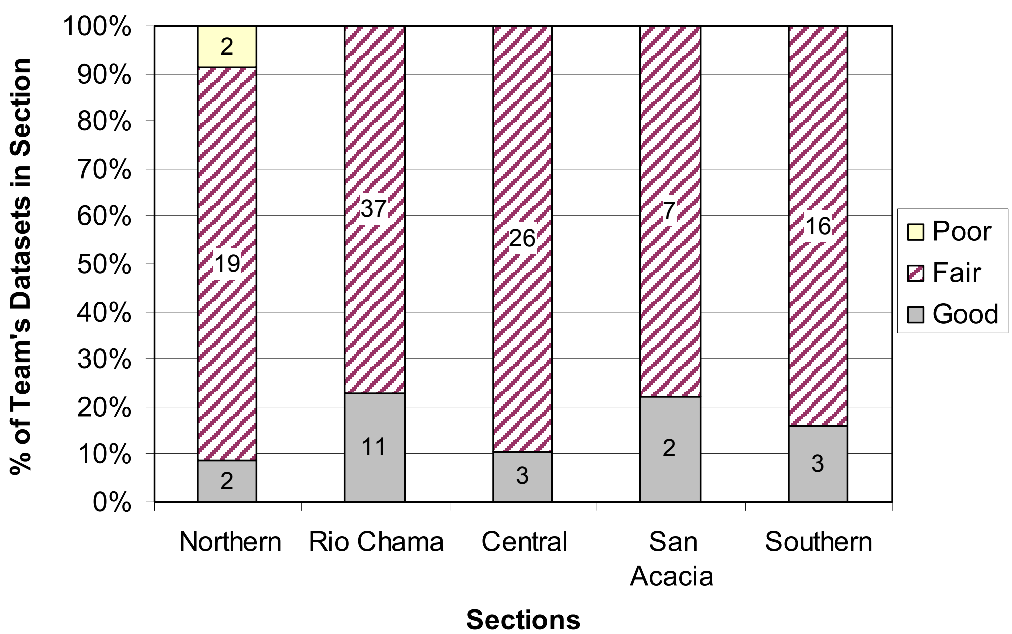


Figure P-30. Land Use, Recreation, Socioeconomics, and Environmental Justice Data Gaps (Excluding URGWOM and FLO-2D Datasets)

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3.0 References

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3.1 ATTACHMENTS

3.1.1 ATTACHMENT A – CD-ROM of Criterium Decision Plus Reader, EIS Decision Analysis File, and Resource Analysis Spreadsheets

Criterium Decision Plus Files

- Decision Analysis Data File – DEIS.cdp
- CDP Reader

EXCEL Files – Resource Analyses

- Aquatic Habitat
- Riparian
- Water Operations
- Water Quality
- Sediment Management
- Tribal Resources
- Cultural Resources
- Land Use
- Agriculture
- Reservoir Recreation
- Recreation
- Hydropower
- Economic Justice