APPENDIX L

CH2M Hill Hydrology Report

City of Albuquerque Public Works Department
Water Resources Strategy Implementation

Hydrologic Effects of the Proposed City of Albuquerque Drinking Water Project on the Rio Grande and Rio Chama Systems

Updated for New Conservation and Curtailment Conditions

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Submitted by

CH2MHILL

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Abbreviations and Acronyms

ac-ft	acre-feet
ac-ft/yr	acre-feet per year
AMAFCA	Albuquerque Metropolitan Arroyo Flood Control Authority
ASR	aquifer storage and recovery
AWRMS	Albuquerque Water Resources Management Strategy
AWRMS-DWP	Albuquerque Water Resources Management Strategy, Drinking Water Project
BBER	Bureau of Business and Economic Research
BLM	U.S. Bureau of Land Management
cfs	cubic foot per second
CMA	critical management area
Corps	U. S. Army Corps of Engineers
CY	calendar year
DEIS	Draft Environmental Impact Statement
DWP	Drinking Water Project
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ft/s	feet per second
FWS	U.S. Fish and Wildlife Service
gpcd	gallons per capita per day
LFCC	Low-Flow Conveyance Channel
mgd	million gallons per day
MRG	Middle Rio Grande
MRGCD	Middle Rio Grande Conservancy District
OSE	Office of the State Engineer
RGSM	Rio Grande silvery minnow
SJC	San Juan-Chama
SWRP	Southside Water Reclamation Plant

URGWOM	Upper Rio Grande Water Operations Model
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
WSA	water service area
WTP	water treatment plant

Executive Summary

Executive Summary

Purpose and Scope

An evaluation was undertaken to estimate and compare the effects of alternative water supply scenarios for the City of Albuquerque (City). The two scenarios examined were the proposed new surface water diversion under the Albuquerque Water Resources Management Strategy (AWRMS) Drinking Water Project (DWP) and a regime of continued ground-water pumping — the No Action alternative. The main purpose was to estimate and compare the hydrologic effects of the DWP and No Action alternatives on streamflow conditions in the Middle Rio Grande (MRG) basin between Cochiti and Elephant Butte Reservoirs, with particular focus on the reach between Angostura and Isleta. Also examined were the DWP and No Action effects on

- The Albuquerque basin aquifer and shallow ground water in the bosque area of the Rio Grande
- Sediment transport and channel conditions in the Albuquerque reach of the Rio Grande
- Reservoir and river control operations in the Rio Chama below Heron Reservoir (referred to herein as the Rio Chama system)

The evaluation forms the basis for addressing hydrologic and related issues to be considered in the Environmental Impact Statement (EIS) currently under preparation by the City of Albuquerque; and for Application No. 4830 at hearing before the Office of the State Engineer (OSE) for a permit to divert from the Rio Grande and fully consume the City's imported San Juan-Chama (SJC) water.

Opinions and Conclusions

Based on the evaluation summarized in this report, we offer the following major opinions and conclusions:

Overall Intent of DWP

- ❑ The proposed facilities and operating plan for the DWP are intended specifically to protect the water rights of others and maintain flows in the Rio Grande, particularly during dry periods. The DWP also is intended to preserve a drought reserve in the local aquifer, minimize changes in shallow water levels in the bosque area of the Rio Grande, maintain the sediment transport regimen of the river, and maintain flows and reservoir levels in the Rio Chama system.
- ❑ Based on the scientific and engineering evaluations completed by the City during the last decade, the City's future water supply needs to be built upon a project (i.e., the DWP) that fully consumes its annual allocation of imported SJC water.

Methodology Used in Evaluating Effects

- Analysis of the Rio Grande hydrologic record indicates that the 1971-98 period provides a representative and appropriate basis for examining the effects of the DWP and No Action alternatives on streamflow conditions in the MRG basin. Use of the 1971-98 record, with the addition of a simulated 3-year drought and appropriate adjustments for the effects of pumping, surface diversions, and wastewater return flows, also provides a logical basis for simulating City water rights offset requirements and balances over the simulated period of 2006-60.

- The OSE interim ground-water model of the Albuquerque basin aquifer, coupled with an interactive 'spreadsheet model' of Rio Grande flows (built upon the adjusted 1971-98 hydrologic record), is a sound tool for evaluation and comparison of the hydrologic effects of the DWP and No Action alternatives. The two-coupled models are termed the AWRMS River Model in this report.

Results of Modeling and Hydrologic Evaluations

- Results of computer runs on the AWRMS River Model indicate that under the No Action alternative (continued pumpage), a simple release of the City's SJC water from upstream storage cannot be effectively utilized to offset net effects on the Rio Grande. That is, with continued City pumpage to meet future demands, the full allocation of the City's SJC water cannot be utilized because the river does not leak to the aquifer at a rate high enough to require the full amount of SJC water [48,200 acre-feet/yr (ac-ft/yr)] to be used as an offset of OSE-calculated effects on the Rio Grande.

- Based on the 1971-98 period of record for the U.S. Geological Survey (USGS) gage at Albuquerque, mean annual flow was 1,410 cubic feet per second (cfs) with monthly means ranging from 2,900 to 3,200 cfs in May and June to 440 to 540 cfs in October and September.

- Over the 2006-60 period (or 2006-40), the DWP and No Action alternatives will have quite similar effects on overall streamflow conditions in the MRG. In general, relative to No Action, the DWP alternative results in more water (about 65 cfs) in the river above the diversion point in Albuquerque (or Angostura), somewhat less water (10 to 30 cfs) in the reach between the DWP diversion and the City's wastewater return near Rio Bravo, and essentially no difference in flows at Isleta.

- Evaluation of individual simulated years in the pre-2040 period representative of normal, low-flow, and drought conditions indicates that river flows under the DWP would be essentially the same or several cubic feet per second higher than under No Action. The higher DWP flows are especially prevalent at the most critical times (i.e., during summer and early-fall months of low-flow and drought years).

- The ability to curtail and/or shut down surface diversions under the DWP offers a decided advantage in terms of maintaining flows during critical low-flow and drought periods. In effect, the DWP can be operated during such periods to ensure more water in the river than there would be under No Action.

- Simulation of water demands and pumpage under No Action indicates that pumpage would reach or slightly exceed the pumping limit under State Permit RG-960 of

155,000 ac-ft/yr by around 2052. In contrast, well pumpage under the DWP alternative would be about 65,000 ac-ft/yr by 2052.

- Projected drawdowns of the Albuquerque basin aquifer in 2040 approach or slightly exceed the OSE-prescribed subsidence threshold of 250 feet in small areas of west Albuquerque and approach 200 feet in small areas of northeast and southeast Albuquerque. Drawdowns in 2040 under the DWP are generally less than 150 feet in the same areas and less than 100 feet elsewhere.
- If pumpage under No Action continued through 2060, large areas of northeast and east Albuquerque would experience drawdowns from pre-development conditions that exceed 250 feet. Corresponding 2060 drawdowns under the DWP would generally be less than 150 feet with the exception of an isolated area in northwest Albuquerque that could approach 250 feet.
- Continued pumping of the aquifer under the No Action alternative results in the removal of 2.0 million ac-ft of water from aquifer storage through 2060. Whereas, operation of the DWP results in the addition of 0.2 million ac-ft of water to aquifer storage.
- Operation of the DWP will not cause significant changes in water depths and velocities in the Rio Grande below the proposed points of diversion at either Angostura or near Paseo del Norte.
- The sediment transport regimen of the Rio Grande will not be affected significantly by operation of any of the alternative DWP diversion facilities.
- Relative to historical conditions, changes in flows and reservoir operations in the Rio Chama should be minimal relative to historic (i.e., 1971-98) conditions.

Bases of Opinions and Conclusions

Supporting information for opinions and conclusions stated above is summarized below with additional details provided in the remainder of the report.

No Action Alternative

The No Action alternative basically consists of a continuation of the City’s ground-water pumping into the foreseeable future with the City’s conservation plan fully implemented as scheduled [i.e., 40 percent reduction in average demand from 250 to 150 gallons per capita per day (gpcd) by 2015]. Under No Action, City wells would withdraw water from the Albuquerque basin aquifer for almost all municipal and industrial needs through the year 2060 — with the following exceptions:

- Up to 3,000 ac-ft/yr of City SJC water will be used for the Nonpotable Surface Water Reclamation project (CH2M HILL, 2000a) recently permitted by the OSE. The SJC water will be released from storage in Abiquiu Reservoir and diverted via a subsurface collection facility beneath the Rio Grande just downstream of Alameda Bridge.

- Provision of City SJC water to honor existing contractual lease agreements with other entities totaling up to 2,600 ac-ft/yr through 2011. After 2011, all the lease agreements will have expired and no further releases of SJC water would be made for this purpose.

Although only small quantities of City SJC water listed above are assumed to be in the Rio Grande below Abiquiu Reservoir under the No Action alternative, this does not mean that the City SJC allotment of 48,200 ac-ft/yr would not be taken from Heron Reservoir each year. But because the timing, amounts, and ultimate uses for the City's allotted SJC water (other than the listed quantities) cannot be predicted, the hydrologic evaluation and modeling analyses presented herein address only the amounts specified above.

In effect, the No Action alternative represents what the City would need to do if the DWP project is not constructed. Or, in other words, how the City would attempt to meet customer water demands if the project to use its SJC water cannot be built.

DWP Alternative

Growing water demands in the latter part of the 20th century, and new research indicating that the Albuquerque basin aquifer is not as extensive or well-connected to the Rio Grande as previously thought, led the City to propose implementation of the DWP. The DWP will fully consume the City's 48,200 ac-ft/yr of SJC water to

- Move toward a sustainable supply
- Create a drought reserve
- Reduce the reliance on mined (non-renewable) ground water
- Facilitate compliance with the new U.S. Environmental Protection Agency (EPA) standard for arsenic
- Greatly reduce the risk posed by large aquifer drawdowns and resulting subsidence damage that could occur under the No Action alternative

Wells would still be used under the DWP, but primarily to meet peak summertime water demands when such demands exceed the capacity of the DWP, and to provide water to areas not readily served by the DWP. Wells also will be used in the event of upstream spills of pollutants and during periods of severe drought and low flows in the river when DWP diversions are curtailed or shut down.

There will be an aquifer storage and recovery element to the DWP (maximum volume of 10,000 to 15,000 ac-ft/yr) whereby treated river water will be injected in City wells during off-peak months. The DWP alternative has the same assumptions for use of non-DWP SJC water as No Action (i.e., honoring of existing lease agreements through 2011 and provision of approximately 3,000 ac-ft/yr for the Nonpotable Surface Water Project).

The proposed DWP, with a start of operation planned for about 2006, is based on release of City SJC water from upstream with diversion in the Albuquerque area by one of three means:

- Use of the existing Angostura diversion dam (5 miles north of Bernalillo) operated by the Middle Rio Grande Conservancy District (MRGCD)
- New surface diversion using an adjustable, low-head, crest-gate-type dam just north of the Paseo del Norte Bridge. The recently submitted Draft Environmental Impact Statement (DEIS) identifies this as the preferred alternative (U.S. Bureau of Reclamation [USBR], 2002)
- New subsurface diversion (under-river horizontal collectors) located north and south of the Paseo del Norte Bridge

Both the Angostura and new surface diversion options of the DWP would include intakes with fish screens and fishway bypass facilities to minimize impacts on river fishes. No fish-related facilities would be required for the subsurface diversion option.

General Operating Plan for DWP Diversions

Under the DWP the City will continue to work closely with those agencies having responsibility in managing the flows of the Rio Grande and Rio Chama. These include the USBR, the U. S. Army Corps of Engineers (Corps), the OSE, and the MRGCD. More recently, because of the critical habitat designation for the Rio Grande silvery minnow, the U.S. Fish and Wildlife Service has become a more active player in flow management on the river. The City, in concert with the above agencies, will monitor snowpack, reservoir storage, seasonal weather forecasts, and other factors beginning in winter. As the critical warm weather irrigation season approaches (usually beginning in April or May), flow forecasts and river management decisions will be updated and specific plans formulated relative to the City's DWP release and diversion program for the coming year.

As discussed in Section 4, the initial years of DWP operation (from about 2006 to 2016) will, under OSE administrative guidelines, require the payback of additional river effects (i.e., river seepage to the aquifer) caused by the lingering effects of past pumpage. Thus, it is important that the City be able to take delivery and store in Abiquiu all of its annual allotment of 48,200 ac-ft/yr in the years 2003-2005 as a basis for a fully operable DWP in 2006.

Although the City's DWP release-diversion plan will undoubtedly change somewhat from year to year, it was necessary in this document to specify specific values of flow, release, and diversion under a hypothetical operation of the DWP to evaluate hydrologic effects. The scenario described below is intended for that purpose, and represents a worst-case condition for evaluation under the EIS and State Permit 4830. Deviations from the simplified release-diversion plan (which are fully anticipated under active management on the Rio Grande) will result in hydrologic effects less than those estimated in this document.

Assuming a diversion in the vicinity of Paseo del Norte Bridge, a simplified explanation of DWP operations is as follows. A constant release of about 66 cfs of City SJC water will be made from Abiquiu Reservoir. After incurring conveyance losses between Abiquiu and

Albuquerque, approximately 65 cfs of SJC water (on average) will reach the diversion facilities. There, a diversion of 130 cfs will occur throughout the year provided flows are at or above a threshold flow of 260 cfs (195 native, 65 SJC) above the diversion point. The 130-cfs diversion will include 65 cfs of City SJC water, and 65 cfs of native Rio Grande water, which serves as carriage water for the diverted SJC water. The 65 cfs of SJC water will be consumptively used within the City's Water Service Area (WSA). The 65 cfs of native water will be returned to the river at the Southside Water Reclamation Plant (SWRP) outfall below Rio Bravo Bridge about 14 miles downstream of the Paseo del Norte diversion point.

Under the DWP and No Action, there will be a reach (about 14 miles) of the Rio Grande between the point of diversion and point of return that will be depleted relative to native flows by around 70 to 100 cfs on average. (Actually, this reach is already being depleted by permitted pumpage under RG-960). Estimates are that DWP flows in the 14-mile reach will generally average 10 to 30 cfs lower than No Action flows (see Figures 5-6 and 5-7; and Table 5-2, Section 5).

To ensure that DWP diversions do not dry up or otherwise adversely affect the riverine ecology between the diversion and return flow points, the City proposes to implement a curtailment strategy as described below.

For the full operation of the DWP under a constant release-diversion scenario, the flow at the diversion point (assumed here to be just north of the Paseo del Norte Bridge) must be at least 260 cfs based on the following:

- A diversion rate of 130 cfs comprised of 65 cfs of SJC water and 65 cfs of native water
- A fishway bypass flow of 50 cfs on the west side of the river
- A flow of 20 cfs at the outlet of the sluiceway on the east side of the river to provide for downstream movement of sediment and fish past the intake screens

The minimum flow bypassing the DWP diversion will be 130 cfs, which is considered sufficient to prevent river drying downstream.

Thus, the total flow required to fully operate the DWP at 130 cfs is (130 + 50 + 20) = 200 cfs. However, in consideration of low flows recorded in 2002, if the river flow above the diversion point is less than 260 cfs, the flow to the intake will be curtailed to ensure proper operation of the sluiceway and fishway facilities, and to minimize depletion effects in the 14-mile reach between the diversion and the SWRP. This curtailment threshold ensures that the Albuquerque reach (diversion to SWRP outfall) will remain wet when the DWP is in operation. This curtailment threshold allows a factor of safety for unusual conditions and higher-than-anticipated depletions over the Albuquerque reach; it also ignores any inflows (e.g., Central Avenue wasteway from the Riverside Drain) that ordinarily occur but might be less-than- normal during low-flow conditions.

When native river flows at the diversion point fall below 195 cfs (total flow of 260 cfs with 65 cfs SJC in the river), the City will begin curtailing the quantity of the diversion by 1 cfs for each cfs of decrease in native flow, but will continue to release and divert the full 65 cfs of SJC water. As native flow continues to drop, DWP diversions will be reduced accordingly. When native flow reaches 130 cfs above the diversion, DWP diversions will cease entirely.

During periods of curtailment, the City will provide increasing amounts of water to the WSA from existing City wells. During periods of complete shut down of river diversions, the WSA will be supplied entirely from City wells.

If the DWP diversion point were at Angostura rather than near Paseo del Norte, the above plan would be identical except that the threshold for curtailment would be about 50 cfs higher (250 cfs after diversions by MRGCD) to account for additional losses in the reach between Angostura and Paseo del Norte.

Hydrologic Baseline

The hydrologic evaluation presented herein uses a hydrologic baseline developed from the 1971-98 streamflow and reservoir record for gages throughout the MRG and Rio Chama basins. This record was chosen because it is representative of (1) the long-term (>100-year) record for key Rio Grande accounting gages at Embudo and Otowi, and (2) the most recent operational program for reservoirs, river facilities, and SJC water importation and use that began in 1971.

The 1971-98 streamflow record was adjusted and aligned so that 1971 became 2006, 1972 became 2007, etc. to simulate future hydrologic conditions with the DWP or No Action alternatives in place. Adjustments to the historic record included:

- Removal of the historical (1971-98) City SJC water that was in the river at and below Albuquerque based on a detailed evaluation of Federal, State, and City records. A supporting evaluation detailing the historical release and use of City SJC water was produced for this purpose (CH2M HILL, 2002a).
- Correction for differences between historical (1971-98) and adjusted future (simulated 2006-60) pumping-induced effects on the river. Such corrections were made using the OSE interim ground-water model of the Albuquerque basin aquifer.
- Correction for differences between historic (measured 1971-98) and adjusted (simulated 2006-60) wastewater returns at the SWRP.
- Addition of a simulated 3-year drought to the record based on three 1972s placed 'back-to-back' in the baseline so as to depict an extended drought similar to that experienced in the 1950s. Such a drought is otherwise missing from the 1971-98 period.

Evaluation of Hydrologic Effects

The proposed release-diversion schedule for the DWP was imposed on the adjusted record to determine the differences (or effects) of the DWP and No Action alternatives on river flows at key gaging locations above and below Albuquerque. Hydrologic effects were examined and compared for the simulated 2006-60 period as a whole, for the period 2006-40, and in more detail for selected years of normal flow, low-flow, and the extended 3-year drought scenarios. Analysis of water quality effects is provided in a separate report (CH2M HILL, 2002b).

Potential impacts on flow depths and velocities in the 'depleted reach' of the Rio Grande between the DWP diversion and the SWRP return flow point also were assessed. For the DWP subsurface diversion option, we also evaluated the likely impacts on riverfront ground-water levels, particularly in the bosque area. Using the OSE interim ground-water model, estimates were made of 2040 and 2060 drawdowns induced in the Albuquerque basin aquifer for the No Action and DWP alternatives.

A preliminary evaluation of sediment transport issues was undertaken relative to the possible operations of the surface diversions at Angostura and Paseo del Norte.

Finally, a series of runs were made using the Riverware© SJC model to simulate No Action and DWP effects in the Rio Chama (in selected dry and normal years) on the ability to make deliveries to all SJC contractors, reservoir operations and water levels, specified fisheries flows, and recreational rafting releases.

The major results of all these evaluations are as follows:

Rio Grande Streamflows

- **Mean Effects Over the 2006-60 Period** — Mean DWP flows are generally higher than No Action flows by about 65 cfs upstream of Albuquerque, 10 to 30 cfs less in the reach between the diversion and SWRP return, and virtually identical downstream of the SWRP return. Also, examination of 'low-flow thresholds' of 130 cfs (representative of about 195 cfs in terms of historical flows) at the Albuquerque gage, suggests little difference between the No Action and the DWP. Under both alternatives, a monthly flow of less than 130 cfs occurs about 7 percent of the time at Albuquerque.

  The simulated effects on river flows actually vary over the 2006-60 time period due to the interplay between ground-water pumping, the lingering effects of past pumping, wastewater returns, the quantities of ground water in wastewater returns, and the amounts of SJC water released over time. For example, during the first decade of the DWP, considerably more than an annual average of 66 cfs of SJC water will be released from Abiquiu by the City to compensate for residual seepage into the aquifer caused by past ground-water pumping and because less mined ground water will be discharged to the river in the form of return flow at the SWRP.

- **Normal Year (2023, based on adjusted 1988)** — DWP flows are about 65 cfs higher than No Action above Albuquerque, about 22 cfs lower at Albuquerque, and essentially the same downstream of Albuquerque.

- **Low-Flow Year (2040, based on adjusted 1977)** — DWP flows are about 67 cfs higher than No Action above Albuquerque, 26 to 29 cfs lower at Albuquerque except during months of curtailment when they are up to 40 cfs higher, and 60 to 70 cfs higher downstream of Albuquerque.

- **Extended Drought (2024 to 2026, based on three-1972s)** — DWP flows are about 67 cfs higher than No Action above Albuquerque, 28 to 35 cfs lower at Albuquerque except in the May-August period of curtailment when flows are 0 to 32 cfs higher, and generally 25 to 43 cfs higher than No Action at sites below Albuquerque.

- **Curtailment Periods --** The higher flow conditions during periods of curtailment simulated for 2024-26 and 2040 above are typical of the improvements and flexibility possible under the DWP during low flows and drought.

Effects on Ground Water and River 'Net Effects'

The No Action alternative is based on ground-water pumping to meet all future City demands, except for the small quantities mentioned previously for the Nonpotable Surface Water Reclamation Project. As such, No Action will have a larger effect than the DWP alternative on the Albuquerque basin aquifer in terms of total drawdowns and drawdown rates. By 2040 drawdowns approach or slightly exceed the OSE-prescribed subsidence threshold of 250 feet in small areas of west Albuquerque and approach 200 feet in small areas of northeast and southeast Albuquerque. Under the DWP, 2040 drawdowns are generally less than 150 feet in the same areas and less than 100 feet elsewhere. By 2060, under No Action pumping, drawdowns throughout most of Albuquerque (Figure 6-3) are predicted to be more than 200 feet [including virtually the entire area recently designated as the critical management area or CMA (OSE, 2000)]. Corresponding DWP drawdowns in 2060 are simulated to be less than 150 feet, with the exception of small areas in northwest Albuquerque where drawdowns are simulated at more than 250 feet.

Localized drawdowns in the critical bosque and riverside drain areas along the river are difficult to model, but review of runs made on the OSE interim ground-water model suggests that bosque-area drawdowns under the No Action alternative could be 1 to 3 feet more than the DWP alternative by 2040 and beyond.

The subsurface collection facility is the only diversion option of the three under consideration for the DWP that will have a significant impact on shallow, riverfront ground water. Up to 3.5 feet of localized drawdowns under the bosque in the Paseo del Norte Bridge area is predicted under the subsurface diversion option.

Effects on River Flow Depths and Velocities

Relative to No Action flows, DWP flows will generally be 60 to 65 cfs higher above the diversion point and a maximum of about 45 cfs less in the reach immediately below the diversion point. However, the effects on flow of either the DWP or No Action alternatives will be quite similar over the entire reach covering the Paseo del Norte (or Angostura) to SWRP outfall section of the river.

An analysis of flow, cross section, and discharge measurements made by the USGS and the USBR were used to establish flow conditions and typical channel characteristics of the 40-mile Albuquerque reach. The method of Leopold, et al. (1964) was used to calculate 'hydraulic geometry' characteristics that were, in turn, coupled with the selected flow conditions to estimate changes in water depths likely to be caused by proposed DWP releases and diversions (again which would be quite similar to those changes caused by No Action pumpage on the river). Results indicated that maximum changes in water depths in the Albuquerque reach caused by DWP will be quite minor — on the order of ±0.1 foot during a mean low monthly flow condition. During severe low flows (e.g., 100 cfs at Albuquerque gage), water levels could be reduced by up to 0.3 foot (relative to historic conditions, probably only about 0.1 foot relative to No Action) in narrowest sections of the river under the DWP diversion scenario.

Inspection of historic discharge measurements made in the river in the vicinity of the Albuquerque gage at Central Avenue (a narrow section) suggests that the reduction in flows of up to 65 cfs (from 135 to 70 cfs) immediately below the DWP diversion would have the following effects:

- Velocity—0.1 to 0.2 foot per second (ft/s) reduction within a typical range of 1.0 to 1.4 ft/s
- Width—20 to 30 feet reduction within a typical range of 70 to 130 feet, respectively

Effects on Sediment Transport

For the DWP alternative, the sedimentation questions relate to how the operation of a surface diversion at the existing dam at Angostura, or of a new diversion near Paseo del Norte, might affect sediment transport in the Rio Grande. Although specific hydraulic evaluation based on actual size and design of the diversion facility will be needed to fully answer such questions, several preliminary conclusions were made based on review of USGS and USBR sediment data and a report by Dr. Richard Heggen (2001):

- The relatively minor amounts of additional SJC water in the Rio Grande caused by operation of the DWP will have no measurable effect on sediment transport characteristics of the river.
- Operation of a renovated Angostura Dam (if selected as the DWP diversion alternative) to divert 130 cfs for the AWRMS project should have virtually no effect on the existing sediment transport regime of the river.
- Operation of a new 3-foot-high adjustable diversion facility near Paseo del Norte (if selected as the DWP diversion alternative) will effect sediment transport, but locally and temporarily rather than reach-wide and permanently.
- Below the diversion structure at the exit of the sluiceway and fishway, there may be accumulations of material; or in some areas, scour holes. Such conditions will be localized and manageable with monitoring and periodic maintenance activities.

Effects in the Rio Chama System Upstream of Cochiti Reservoir

To evaluate and compare the effects of the DWP and No Action alternatives on hydrologic conditions in the Rio Chama system, a simplified version of the SJC Riverware© model was used (CH2MHILL, 2001c) based on a computer code developed by the multi-agency Upper Rio Grande Water Operations Model (URGWOM) Team (2000). The model focused on evaluation of effects on flows in the Rio Chama, particularly the capability to maintain historic summertime recreational rafting releases and winter fishery releases.

The DWP scenario evaluated by the Riverware© model had the full City allotment of 48,200 ac-ft/yr in the system, whereas the No Action scenario assumed no City SJC water in the system. As noted previously, there will be at least limited amounts of City SJC water in the system under No Action. However, the amounts are so small as to not be reasonably simulated in the SJC Riverware© modeling analysis done for this report. Thus, evaluation of the No Action alternative without City SJC in the system (CH2M HILL, 2001c) brackets the full range of possibilities for comparing hydrologic effects in the Rio Chama system.

Comparisons were made between simulated conditions with the DWP and the No Action alternatives based on the 1971-98 hydrologic record. As was the case for the evaluation of flows at the MRG gaging stations mentioned previously, 1977 and 1988 were chosen as representative of low-flow and normal years, respectively, for simulation by the SJC Riverware© model. A 3-year drought period was simulated by running 1972 'back-to-back' three times. Curtailed SJC deliveries (as described previously) occurred during both the 1977 and 3-year drought modeling scenarios.

Model runs for the Rio Chama system were used to compare the following:

1. Ability to maintain rafting releases in the Rio Chama below El Vado.
2. Ability to maintain winter fisheries releases in the Rio Chama below El Vado and Abiquiu.
3. Reservoir levels — i.e., maximum and minimum volumes and elevations for the DWP and No Action simulations relative to each other and to those experienced during the historic (1971-98) period.

Results of the SJC modeling analysis are summarized as follows (see Section 7 for details):

- Summertime rafting releases and winter fisheries releases are maintainable under the DWP alternative. However, under the worst-case No Action assumption (no SJC water available), simulations suggest that some of the rafting releases could not be made in low-flow and drought periods.
- Rafting releases in summer under the DWP scenario require the early delivery of considerable quantities of City SJC water to Abiquiu Reservoir during the peak period of reservoir evaporation. Preliminary evaluation suggests that meeting the historical schedule of rafting releases could cause an additional evaporative loss of several hundred acre-feet per year of City SJC water (in some years) that would diminish the quantity of water available for the DWP. Obviously, the City would need such losses to be fully replaced or compensated to ensure a fully operable DWP.
- Regarding reservoir levels, model simulations suggested that the DWP alternative should not markedly change historic maximum and minimum storage volumes and water surface elevations of SJC reservoirs.

Section 1

Introduction

SECTION 1

Introduction

Purpose

The Drinking Water Project (DWP) and the No Action alternative (continued pumping), their operation and their effects on Rio Grande flows and the Albuquerque basin aquifer, are the focus of the evaluation presented in this report. Of particular importance are the estimated hydrologic effects of the DWP and No Action scenarios on streamflow conditions in the Middle Rio Grande (MRG) basin between Cochiti and Elephant Butte Reservoirs (with a focus on the reach between Angostura and Isleta). Also examined are potential hydrologic effects on reservoir and river control operations in the Rio Chama below Heron Reservoir (referred to herein as the 'Rio Chama system').

Background

The City of Albuquerque (City) plans to implement the Albuquerque Water Resources Management Strategy (AWRMS), of which the Drinking Water Project (DWP) is the key element, to provide a sustainable municipal and industrial water supply into the middle of the 21st century. Approved by the City Council in 1997 (CH2M HILL, 1997a), AWRMS is a multi-faceted project that involves diversion and use of imported San Juan-Chama (SJC) water for most of the City's future drinking water supply. Besides the Drinking Water Project (DWP), the overall AWRMS program includes a conservation program, aquifer recharge, reclamation and reuse of wastewater for irrigation and industrial needs, and several other elements.

The SJC water used in the DWP will provide a new surface supply for conjunctive management with the ground-water resources of the Albuquerque basin aquifer. Without the new SJC supply, continued pumpage by City wells would cause the aquifer to be seriously depleted and potentially subject to subsidence problems over the next 50 to 60 years (see subsequent section**,** *Effects of No Action and DWP Alternatives on the Albuquerque Basin Aquifer*). Ground water will still be used to help meet peak summertime demands and to provide most of the City's water during periods of drought or low flow in the river when DWP diversions are curtailed or shut off. In winter months when customer demands are low, treated river (SJC) water will be recharged into the aquifer using City wells.

Using one of three alternatives for diverting water from the Rio Grande, the DWP will allow the City to consumptively use its full allotment of SJC water for municipal and industrial purposes. A brief summary of the three diversion alternatives follows below. Refer to Figure 1-1 for location of near-river features. For additional details of DWP alternatives summarized below, see CH2M HILL (2001a and b).

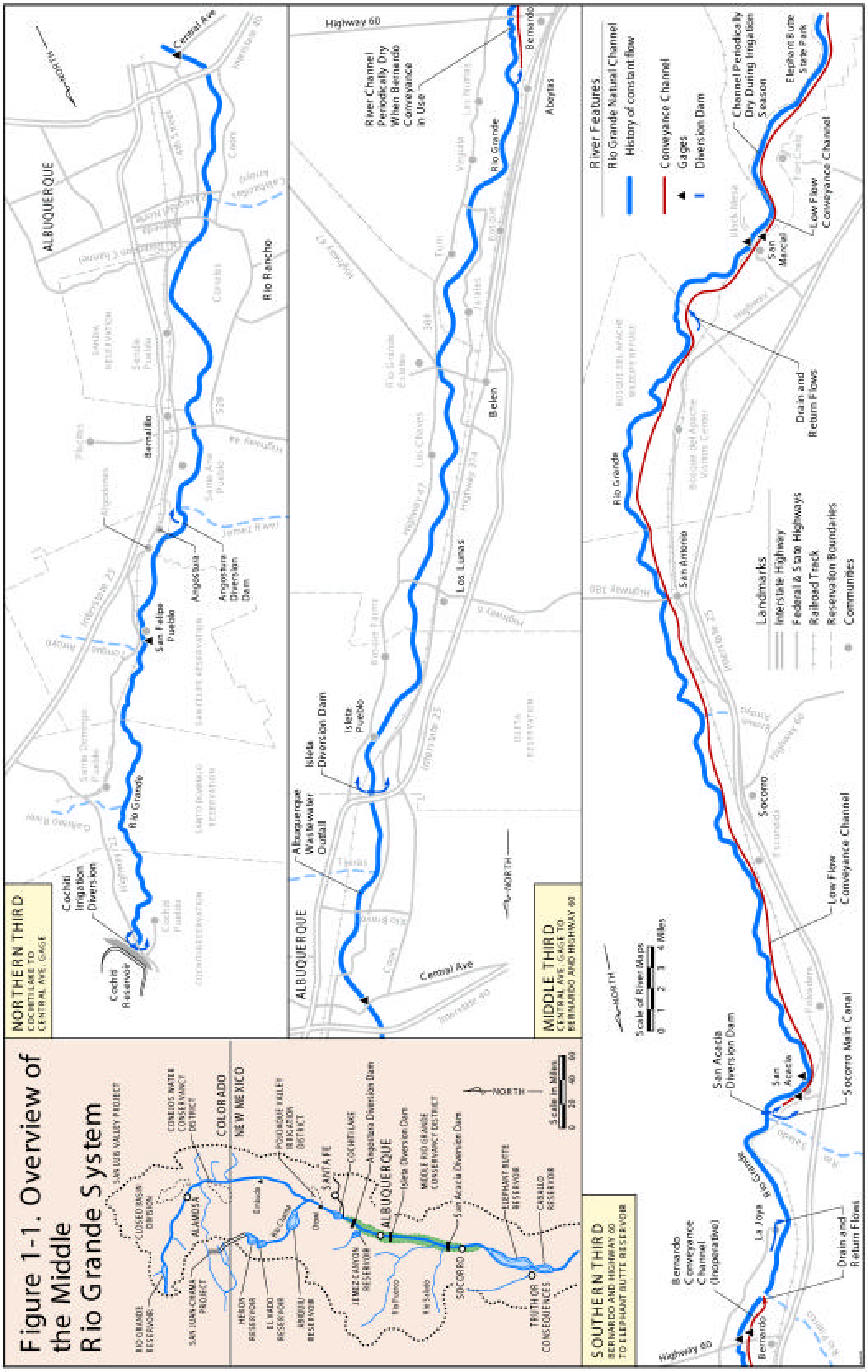


Figure 1-1. Overview of the Middle Rio Grande System

A. **Angostura Diversion —** This alternative involves diversion of river water at the existing Middle Rio Grande Conservancy District (MRGCD) dam near Algodones about 5 miles upstream from Bernalillo. The Atrisco feeder and / or the Albuquerque main canal would be used to convey water to a proposed pump station just north of the confluence of the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) North Diversion Channel and the Rio Grande (about 1.5 miles upstream of the Alameda Bridge). A 66-inch-diameter pipeline would convey water from the pump station along the north and east sides of the AMAFCA North Diversion Channel to the City's proposed Chappell Drive water treatment plant (WTP) near the intersection of Chappell Drive and Osuna Road in northeast Albuquerque.

B. **New Surface Diversion —** Diversion would occur by means of a new low-head, adjustable-height dam located north of the Paseo del Norte Bridge. Conveyance would be by 66-inch pipeline along the north side of Paseo del Norte and the east side of the AMAFCA North Diversion Channel, and then to the Chappell Drive WTP. This is the preferred alternative identified in the Draft Environmental Impact Statement (EIS) for the DWP [U.S. Bureau of Reclamation (USBR), 2002].

C. **Subsurface Diversion —** This alternative would be a subsurface (under-riverbed) diversion using perforated pipes or well screens ('horizontal collectors') constructed in trenches backfilled with gravel. The collectors would be buried beneath the bed of the Rio Grande south and north of the Paseo del Norte Bridge over a 1.5-mile reach. Conveyance would be by 66-inch-diameter pipeline along the north side of Paseo del Norte and the east side of the AMAFCA North Diversion Channel to the Chappell WTP.

In terms of effects on Rio Grande flows, the New Surface Diversion and Subsurface Diversion alternatives are considered essentially identical. The Angostura Diversion alternative, by virtue of its location some 19 miles upstream of Paseo del Norte Bridge, would have somewhat different effects on river flows (see subsequent discussion).

Each of the three DWP diversion alternatives would meet the same basic criteria:

- **Capable of reliable delivery of 94,000 acre-feet per year (ac-ft/yr), 130 cubic feet per second (cfs) or 84 million gallons per day (mgd) on average, of water from the river to the City.** This is about twice the City's usable SJC allotment (assumed herein at 47,000 ac-ft / yr) after delivery losses from Heron Reservoir). Diversion of twice the SJC allotment allows full consumptive use of SJC water with roughly 47,000 ac-ft / yr of 'borrowed' Rio Grande (or native) water returned at the City's wastewater treatment plant outfall below Rio Bravo Bridge.
- Pumping and treatment facilities are **sized for a nominal hydraulic capacity of 92 mgd,** or about 143 cfs, to permit flexibility in operation, response to unusual short-term demands, and to provide for continuous operation at 92 mgd in the future if water is available and demand warrants. Diversion and conveyance pipeline facilities are sized such that they could hydraulically handle future flow rates up to 120 mgd or 186 cfs. During peak diversion a maximum of 65 cfs of native water would be diverted and returned to the Rio Grande at the City's wastewater treatment plant outfall below Rio Bravo Bridge.

- **Diversion facilities must be 'fish friendly' to the extent possible**. The Angostura and New Surface Diversion alternatives assume the need for a fishway bypass and for a fish screen on intake facilities to minimize impacts on the endangered Rio Grande silvery minnow (RGSM) and other fishes. The fishway bypass assumes the need for a minimum flow of about 50 cfs in a shallow 'V-shaped,' riprap-lined channel similar to a design developed by the U.S. Bureau of Reclamation (USBR) River Analysis Group in Albuquerque (verbal communication, Drew Baird, USBR, 2000). A fish screen facility will be part of either of the two surface diversion alternatives.

Scope

The scope of this report is summarized below:

- Summarizes historical Rio Grande streamflow conditions, the importation of SJC water, and the City's use of and rights to water in the MRG basin (Sections 2 and 3).
- Documents annual and monthly flows of the river at gaged locations between Otowi and San Marcial and estimates the contribution of imported SJC water to native Rio Grande flows during the period of operation of the SJC project from 1971 to 1998 (Section 3).
- Defines the No Action and DWP alternatives, including an operational scheme for release and diversion of SJC and native Rio Grande water beginning in the assumed first full year of DWP operation in 2006 (Section 4).
- Defines a 'hydrologic baseline' using various adjustments to the 1971-98 streamflow record, including the historical effects of City well pumpage and wastewater returns on river flows and the use of the City's SJC water by others. This analysis is based on a coupled series of streamflow spreadsheets and a ground-water model [Office of the State Engineer (OSE) interim model] of the Albuquerque basin, which we have collectively termed the AWRMS River Model (Sections 4 and 5).
- Uses the AWRMS River Model to compare the effects on Rio Grande flows caused by the No Action and DWP alternatives in dry and normal (near average) years, and under a simulated 3-year drought (Section 5).
- Addresses the effects of the No Action and DWP alternatives on flows between the proposed diversion points (at Angostura or the Paseo del Norte vicinity) and the wastewater return outfall below Rio Bravo Bridge in south Albuquerque (Section 5).
- Estimates the potential effects of DWP and No Action diversions on depths and velocities of the Rio Grande in the Albuquerque reach (Section 5).
- Evaluates the effects of the DWP and No Action alternatives on water depths and flow velocities in the Albuquerque reach of the river (Section 5).
- Provides an overview of sediment transport issues related to DWP diversion facilities (Section 5).

- Compares the effects of the DWP and No Action alternatives on aquifer-wide water levels and changes in aquifer storage; and evaluates changes in localized, shallow water levels along the Rio Grande (Section 6).
- Uses the recently developed Riverware© model of the Rio Chama system formulated by a multi-agency group [Upper Rio Grande Water Operations Model (URGWOM) group] (2000) to examine the effects of the No Action and DWP alternatives on reservoir levels, rafting water releases, fisheries releases, etc (Section 7).

Besides the narrative, tables, and graphs in the main body of the report, there are five appendices. Appendix A provides background on major river control facilities and operating procedures. Appendix B gives a summary of historical amounts of total SJC water and City SJC water in the river at Otowi and Albuquerque for the 1971-98 period. Appendix C includes historical annual and monthly streamflow data summaries for a number of MRG gages. Appendix D summarizes simulated No Action and DWP flows at a number of MRG gaging sites for the period 2006-60 and discusses 'loss factors' for SJC water used in the simulations. Appendix E provides an overall water balance summary (including OSE-calculated 'net effects') of the DWP and No Action alternatives for the simulated 2006-60 period.

Section 2

Water Resources Background

SECTION 2

Water Resources Background

The MRG basin encompasses approximately 12,000 square miles and extends some 150 miles from Cochiti Reservoir on the north to Elephant Butte Reservoir on the south (see Figure 1-1). The Rio Chama basin, adjoining the northwest portion of the MRG basin, is also of importance since it provides the means for conveyance of the imported SJC water to the Rio Grande above the U.S. Geological Survey (USGS) gaging station at Otowi. As used in this report, the Rio Chama system includes those river and reservoir facilities on the Rio Chama that are operated to store and convey imported SJC water to the Rio Grande at Espanola (several miles above Otowi).

River Management and Control Facilities

The management of streamflow in the Rio Grande, including SJC water, occurs within the framework of the Rio Grande Compact. The Compact Commission, established in 1929, is composed of a Federal chairperson and one representative each from Texas, New Mexico, and Colorado. The USBR, the U.S. Army Corps of Engineers (Corps), and the International Boundary and Water Commission are involved in determining the timing and amount of flow by management of reservoir releases from Cochiti Reservoir on the Rio Grande, and Abiquiu, Heron, and El Vado Reservoirs in the Rio Chama basin. As a result, for most years and seasonal conditions, and particularly during droughts or periods of debit or noncompliance as defined by the Compact, there are specific operating rules on the river.

Major river control facilities include two dams on the Rio Grande main stem — Cochiti on the north and Elephant Butte on the south. Above Cochiti there are two major dams on the Rio Chama— El Vado and Abiquiu, and Heron Reservoir on Willow Creek (see Figure 1-1). As detailed in Appendix A, Cochiti and Abiquiu Reservoirs are operated by the Corps primarily for flood control purposes, although there is over-year storage allowed at Abiquiu for up to 170,900 ac-ft of City SJC water (200,000 ac-ft, total).

Irrigation Facilities and Croplands

Between Cochiti and Elephant Butte Reservoirs on the Rio Grande, there are three diversion dams — Angostura, Isleta, and San Acacia (diversions also occur immediately below the outlet works at Cochiti Dam). These structures divert water from the river to the MRG Project system of canals and laterals for irrigation of 50,000 to 65,000 acres of croplands, including up to 8,300 acres of Pueblo croplands. A series of riverside drains intercept and collect water, both surface water and shallow ground water, and convey it back to the river at numerous locations (wasteways). Additional information on cropped acreages and a schematic of diversion and return flow points on the main channel of the Rio Grande between Cochiti and San Acacia is included as Figure A-2 in Appendix A. Note that in Figure A-2, there are no diversions for MRGCD irrigation on the Rio Grande between the proposed alternate points of DWP diversion at either Angostura or in the vicinity of the Paseo del Norte Bridge.

Presently, much of the land bordering the river in the MRG basin (of which 50,000 to 55,000 acres has been irrigated in recent years) is managed for irrigated agriculture by the MRGCD. The MRGCD operates a vast irrigation network (known as the Middle Rio Grande Project) that includes more than 800 miles of canals and 380 miles of drains between Cochiti and the north boundary of the Bosque del Apache National Wildlife Refuge above San Marcial. Riparian areas along the river are owned or managed by the MRGCD, Indian Pueblos, USBR, U.S. Fish and Wildlife Service (FWS), U.S. Bureau of Land Management (BLM), the Corps, U.S. Forest Service, City Open Space, and several State agencies.

The aforementioned Federal and State agencies (including MRGCD) and local interests have all invested heavily in facilities to manage the flows of the Rio Grande. Since 1905, when Congress authorized the Rio Grande Project to control the area below Elephant Butte Reservoir, the river

> *"… has been converted from an essentially natural stream to a highly modified water storage and conveyance system with extensive flood control structures. More recent changes … enhance conveyance and irrigation … . Dams and levees have all but eliminated former seasonal floods … . Former floodplain regions have been converted to productive agricultural lands and, more recently, to urban communities. Irrigation diversions create low-flow conditions, and at times a dry river bed, in much of the reach downstream of Bernalillo." (Bullard and Wells, 1992).*

Potential acreages served by the major diversions based on most recent MRGCD records are approximately as follows:

- Cochiti – 6,300 acres (Cochiti Division)
- Angostura – 12,000 acres (Albuquerque Division)
- Isleta – 33,000 acres (Belen Division)
- San Acacia – 12,800 acres (Socorro Division)

A graphical summary of MRGCD croplands for the last several decades — total, irrigated, and fallow lands — is provided as Figure A-1 in Appendix A. As indicated in Table 2-1, in recent years more than half the irrigated acreage in the MRG Project system was in the Belen Division.

TABLE 2-1
Irrigated Acreage in the MRGCD System

Division	1997 Irrigated Acreage	% of Total	1998 Irrigated Acreage	% of Total
Cochiti	3,770	7	3,440	7
Albuquerque	7,210	14	7,180	14
Belen	29,100	56	28,600	56
Socorro	11,700	23	11,900	23
Total	51,800	100	51,100	100

Source: Bill Miller, URGWOM Team (written communication), November 2000.

A typical MRGCD irrigation year includes the following general schedule and operation.

March through May — The irrigation season formally opens in early March when the MRGCD begins diversions to 'prime' the main canals and ditches below the major diversions at Cochiti, Angostura, Isleta, and San Acacia. This is normally the beginning of the spring snowmelt period and average flow from Cochiti is more than 1,100 cfs, an amount sufficient to meet these initial diversion needs. Because actual irrigation is limited during early March, much of the water diverted for 'priming' flows back to the river via wasteways and drain returns. As more lands are irrigated in late March, river flow has increased correspondingly, and the river below San Acacia continues to flow. By mid-April, flows out of Cochiti are normally >2,000 cfs so that irrigation demand is usually easy to meet. Thus, the river normally has a strong flow past San Acacia. However, in dry years such as 1996 and 1999 when there was little snowmelt runoff in the early spring, the MRGCD demand can take most or all of the natural flow by San Acacia. The MRGCD's stored Rio Chama ('native' water) and imported SJC water is held in storage at El Vado. The MRGCD takes delivery of its allotment of SJC water annually and stores 'native' water as it is available, usually by capture during the spring runoff. With snowmelt runoff generally peaking in late May to early June, full MRGCD irrigation demand is ordinarily met with natural flow without the need for water from storage.

June to Mid-July — Natural flow in the river is usually sufficient to meet the MRGCD irrigation demand at least until the end of June to early July. This is often the hottest period of the year, and consumptive use by crops, riparian vegetation, water surface, and wetted-soil evaporation is at a maximum. Further, June is one of the driest months of the year in the MRG basin. July usually brings a recession of the runoff to the point that 'native' flows reach, and then fall below, MRGCD demand. Historically, this has led to dry reaches of river below the Isleta and San Acacia diversions, although in most years, the Isleta-to-San Acacia reach continues to flow from return flows from wasteways and drains. Return flows below San Acacia go to the low-flow conveyance channel (LFCC) rather than the river, again sometimes resulting in dry spots between San Acacia and San Marcial. Whereas in June there are usually few thunderstorms to provide local runoff to 're-wet' dry sections of river, the monsoonal thunderstorms are more common in July; and wetting and reconnecting the dry sections of river is more likely to occur. When the natural flow drops below irrigation demand, water (both 'native' and SJC) stored in El Vado is released by the MRGCD.

Mid-July through October— Hot weather and high consumptive loss of water often continues in the MRG Project area through early September. However, this also is the peak of the monsoon season and there are periodic inputs of thunderstorm runoff that add to the flow of the river. Even with thunderstorms, the MRGCD must commonly supplement river flow with release of water from storage in El Vado throughout the mid-July to October period. Low-flow (or dry) portions of the river normally lengthen, except that thunderstorms can lessen the frequency and duration of such reaches in some years. The irrigation season ends formally on the last day of October, but irrigation demand diminishes considerably by mid-month. Curtailment of diversions, and returns and seepage to the river, cause increases in river flows beginning in late October. Release of water from storage in El Vado is correspondingly curtailed, allowing any water remaining in storage to be carried over to the following year. From the end of October through March of the following year, the MRG Project irrigation diversions cease (diversions in Colorado and northern New Mexico have also stopped) and base flow of the river insures a continuous flow throughout the Cochiti-to-Elephant Butte reach.

City's Water Resources

Water resources potentially available to the City include:

- Ground water from the Albuquerque basin aquifer. The City has a master well permit (OSE RG-960) that allows pumping of up to 155,000 ac-ft / yr of ground water so long as the effects of that pumping on flow of the Rio Grande are offset.
- Surface water from the aforementioned SJC project. The City has rights to fully consume its allocation of 48,200 ac-ft / yr delivered from Heron Reservoir.
- Vested and acquired surface water rights in the MRG basin amounting to approximately 24,019 ac-ft / yr as of December 2002 (the 2001 amount of 23,347 ac-ft / yr has been used for computational purposes throughout this document). These are consumptive rights obtained over the years for use by the City.
- Treated effluent from the Southside Water Reclamation Plant (SWRP), which discharges to the river just below the Rio Bravo Bridge (see schematic in Appendix A). The City receives return flow credit for this discharge.

Ground Water, Well Pumpage, and Relation to River Flows

Presently, ground water provides all of the City's potable water. The water comes from the Albuquerque basin aquifer, comprised of extensive sand and gravel deposits beneath the Rio Grande valley and adjoining mesas. These deposits extend from north of Bernalillo to south of Belen. The City currently pumps about 110,000 ac-ft / yr from the aquifer from a system of more than 90 wells located throughout the service area. In the recent past (e.g., 1989) before implementation of a conservation program, City ground-water pumpage was more than 128,000 ac-ft/yr.

Customer demands, based on population trends [Bureau of Business and Economic Research (BBER), 1993], tempered by an ongoing water conservation program, are expected to grow to more than 160,000 ac-ft/yr by 2040, and to nearly 200,000 ac-ft/yr by 2060 (CH2M HILL, 1995). This assumes that per capita demands from 2005 to 2060 will be about 175 gallons per day and that population will increase at a declining rate varying from about 1.8 percent in the first decade to about 1.0 percent after 2040. With the implementation of a 150-gallons-per-capita-per-day goal, customer demands are expected to be nearly 140,000 ac-ft/yr by 2040, and to exceed 165, 000 ac-ft/yr by 2060.

The Rio Grande and the basin aquifer are connected hydrologically. That is, pumping of the aquifer lowers the ground-water table, which causes river water to infiltrate (or recharge) the aquifer. Thus, in the 1950s the OSE recognized the possible impacts of river water 'lost' to the aquifer and not available to downstream users or for Rio Grande Compact deliveries to Texas and Mexico. Consequently, the OSE began estimating the need for Albuquerque's water rights required to offset the net effects of the City's pumping on Rio Grande flows. Essentially, these effects are the estimated reduction in flow caused by ground-water pumping, less the wastewater effluent returned to the river at the SWRP below the Rio Bravo Bridge.

Technical studies in the '50s and '60s by the USGS suggested the City's pumping would begin having a negative net effect on Rio Grande flows in the late 1980s (subsequently revised to the mid-1990s). These studies also determined that river and mountain-front recharge and the large size of the Albuquerque basin aquifer provided the City with a virtually limitless supply of ground water. However, hydrogeologic studies and modeling investigations performed in the '90s (New Mexico Bureau of Mines and Mineral Resources, 1992; USGS, 1993, 1995) suggested otherwise. Essentially, the size of the highly productive zone in the aquifer was found to be smaller than previously estimated. The new work further suggested that the effects on Rio Grande flows caused by pumping were less (i.e., less seepage from the river to the aquifer) than originally assumed.

The most recent published work by USGS and the OSE (Kernodle, 1998; Barroll, 1999) has added more refinement to the 1995 USGS ground-water model. The OSE interim model, based on the USGS computer code MODFLOW, is a three-dimensional model that simulates aquifer conditions in the Albuquerque basin. This model has been used by CH2M HILL in this report to evaluate the effects of City well pumpage on infiltration of water from the river to the aquifer. Selected details of the OSE interim model are summarized below:

- Number of Modeled Layers and Cells = 6 and 40,680, respectively
- Hydraulic Conductivity of Undifferentiated Rio Grande Alluvium, 150 feet per day. This value is considered to be on the 'high side' of values obtained from aquifer tests. So, use of the value of 150 feet per day in the OSE interim model leads to high estimates of losses of river water to the underlying Upper Santa Fe deposits.
- Hydraulic Conductivity of Upper Santa Fe Unit (overall, the most important layer in the model in affecting infiltration from the river to the aquifer) = 15 feet per day

- Specific Yield and Specific Storage = 0.20 and 1.0E-6 / foot, respectively
- Anisotropy Ratio = 750 (ratio of horizontal to vertical hydraulic conductivity)

A complete description of the modeled area, boundary conditions, and other details of the model is provided by its authors (USGS, 1995; Kernodle, 1998; Barroll, 1999).

San Juan-Chama Water

Besides the irrigation needs of the MRGCD, the City, and other users in New Mexico recognized a need for additional water to ensure reliable future municipal supplies. Consequently, New Mexico Senator Clinton Anderson led an effort to approve the SJC project that led to preliminary Congressional authorization in 1956 within the *Colorado River Project Storage Act*, *PL 84-485*. The SJC project became a reality with *PL 84-485*, authorization of the companion Navajo Indian Irrigation Project, and initial funding of both projects through passage of *PL 87-483* in 1962.

The USBR built the SJC project (completed in 1970) to provide water to supplement native Rio Grande flows for irrigation and for municipal / industrial needs in the MRG; and to provide limited quantities of water to users above Otowi, such as the towns of Taos, Red River, Espanola, etc. The need for supplementing native flows of the Rio Grande grew first from the realization (as early as the 1930s) that the available river flows were inadequate for irrigated agriculture in the MRG Project area — a situation that reached critical proportions during the prolonged drought of the early and mid-1950s. Also, by the 1950s, it became obvious that additional municipal and industrial water would be needed for the rapidly growing Albuquerque area.

The completed SJC project (Figure 1-1) includes facilities to divert water from the San Juan River basin in southern Colorado, convey it through 26 miles of tunnels under the Continental Divide, and discharge it into Heron Reservoir located on the Willow Creek drainage, a tributary of the Rio Chama. Heron Reservoir was built specifically to accept and store the diverted San Juan water. The diverted SJC water is subsequently released and conveyed for additional storage at El Vado (for the MRGCD) and Abiquiu Reservoirs (for the City) before release via the Rio Chama into the Rio Grande at Espanola. The Nambe Falls Dam and Reservoir operate as part of the SJC project by storing and using native Rio Grande flows with offsets provided by SJC releases. Cochiti and Jemez Canyon Reservoirs (while not part of the SJC project) have been involved in the storage and management of some SJC water — although to a considerably smaller degree than El Vado and Abiquiu.

The Albuquerque Area office of the USBR, Water Operations Division, is responsible for operation and water accounting of the SJC project in accordance with project purposes and the Rio Grande and Upper Colorado Interstate Compacts. The diversion, storage, conveyance, and delivery of SJC water is accomplished by the USBR with technical review by the Engineering Advisors of the Rio Grande Compact Commission who represent each of the states of New Mexico, Colorado, and Texas. This is done to ensure that SJC and native waters are properly accounted for under terms of the various compacts.

Following passage of *PL 87-483*, the City executed a contract for SJC water with the United States in 1963 and amended in 1965. Construction began several years later and was completed in 1971. The City's contract did not provide for its full 48,200 ac-ft/yr allocation to be taken immediately. Rather, for the first 10 years (1972-1981) only 17,700 ac-ft/yr was available, with the remaining portion of the City's allotment used to fill Heron Reservoir to ensure a firm yield for future SJC deliveries to all contractors. In 1982, the full 48,200 ac-ft/yr amount was first provided for release from Heron Reservoir to the City. Deliveries of City SJC water from Heron have occurred every year from 1972 through 1999, as have MRGCD deliveries (which also occurred in 1971).

To date (2002), City SJC water has not been used to offset river depletions (i.e., OSE net effects), except for 1994 when small releases of some 2,000 ac-ft were made based on offset requirements for 1992 and 1993 as calculated by the original OSE method (subsequently superceded by the OSE interim model). Since the mid-1990s, the City's vested and acquired native water rights have more than offset the calculated depletions. Because the City has not yet needed SJC water for municipal purposes or for offsetting depletions (despite City expenditures of some $45 million on the SJC project), most of its SJC allocation not stored in reservoirs has been made available for other users (primarily the MRGCD) since 1972. MRGCD used about 41 percent of the City's SJC allocation of 0.94 million ac-ft between 1971 and 1998. Evaporative losses, water in storage (primarily at Abiquiu Reservoir), and City SJC water used by others (primarily upstream of Albuquerque) under other agreements also have made up more than 40 percent. Other uses, minor losses, and unaccounted water make up the remainder. Refer to Appendix B for a brief summary accounting of City SJC water over the period 1971-98. Additional details are presented elsewhere (CH2M HILL, 2002a, in press).

Rio Grande Surface Water Rights

The City became vested with ground-water rights based upon its history of ground-water pumping prior to the OSE declaration of the Rio Grande Underground Water Basin in November 1956. The 1956 OSE declaration resulted in a quantification of City's vested consumptive rights for Rio Grande ('native') water at 17,875 ac-ft/yr. The City also has acquired additional consumptive rights of about 6,144 ac-ft/yr as of December 2002. Thus, the total consumptive native rights owned by the City as of 2002 were 24,019 ac-ft/yr. As of 2001, the City had a total of 23,347 ac-ft/yr of vested and acquired rights. The 23,347 ac-ft/yr is used throughout this document for computational purposes.

Treated Effluent

The fourth component of the City's existing water resources is the treated effluent discharged at the SWRP and returned to the Rio Grande below Rio Bravo Bridge. Somewhat less than half (about 46 percent based on most recent City records) of the water pumped by the City is used consumptively. This is water that evaporates, is transpired by vegetation, or ends up as deep percolation, some of which may eventually recharge the aquifer. The rest — currently about 60,000 ac-ft/yr — is discharged as treated wastewater to the river. Based on population trends and assuming that 46 percent of the water is consumptively used, return flow to the wastewater treatment plant is projected to increase to nearly 82,000 ac-ft/yr by 2040 and 98,000 by 2060 (see Appendix E).

Example Water Rights Balance

An example of how a total water rights balance might be calculated for City water resources in the year 2000 is summarized in Table 2-2.

TABLE 2-2
Estimates of City Water Rights and Effects on Rio Grande Flows Based on OSE Interim Model, Year 2000

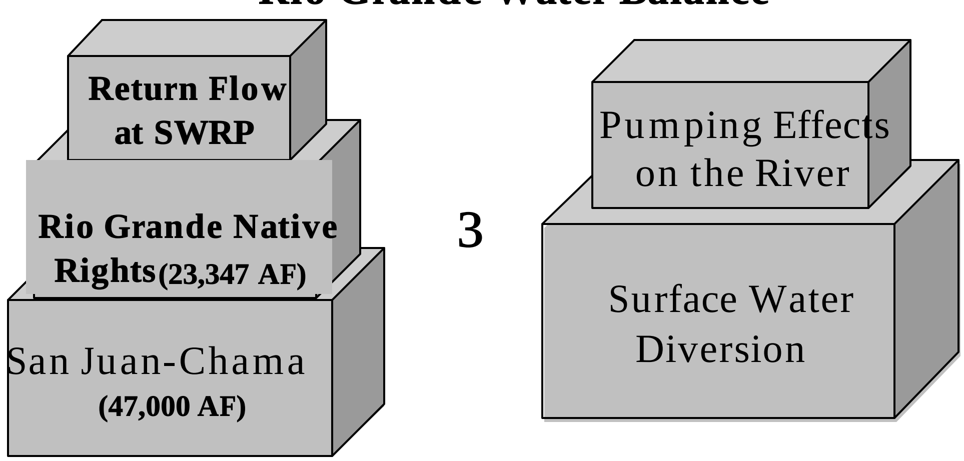
Water Balance Component	Amount in ac-ft/yr
1. City Pumping Rate	114,236
2. Reduction in Streamflow Caused by City Pumping (as per OSE model)	71,687
3. Pumped Water Discharged to River as Treated Effluent (measured)	58,128
4. Net Effect of City Pumping on River (2. minus 3.)	13,559
5. Remaining Native Water Rights (23,347 ac-ft [a] total available minus 4.)	9,788
6. Available SJC Water (48,200 ac-ft less conveyance losses)	≈47,000
7. Total Water Rights Available for Future Use (5. plus 6.)	56,788

[a] City water rights as of December 2002 were approximately 24,019 ac-ft/yr.

The year 2000 was selected for analysis using the OSE interim model, the latest ground-water model of the Albuquerque basin. As shown in Table 2-2, application of the OSE interim model method indicates that in 2000 the net effect of the total City pumping on river flows was about 9,788 ac-ft/yr; and that the total water available to the City for future consumptive use was about 56,788 ac-ft/yr.

In actuality, the above water balance will change in each future year. If the DWP is successfully implemented in 2006, the water balance calculation will become more complicated owing to the use of diverted native and SJC water and a reduced level of pumping from the Albuquerque basin aquifer. However, the logic of the water rights balance will remain unchanged as shown below — return flows at the SWRP plus the available native and SJC rights must be equal to or greater than the OSE calculated pumping effects on the river plus the net surface water diversion.

Rio Grande Water Balance



Section 3

Historical River Flows and Hydrologic Baseline

SECTION 3
Historical River Flows and Hydrologic Baseline for OSE Permit

For purposes of evaluating and comparing the effects on river flows of the DWP alternative versus the No Action alternative, it is necessary to define a hydrologic baseline. We concluded that the streamflow record for the 1971-98 period would best serve for such a baseline for several reasons:

- Representative of the long-term (>100-year) record of gaged Rio Grande flows, with the exception of the prolonged drought such as occurred in the 1950s;
- Representative of the period of imported SJC water in the river with Heron Reservoir in operation;
- Period of upstream regulation by Abiquiu and Cochiti Reservoirs and engineered channel improvements for flood control and low-flow conveyance;
- The most recent period and for which good correlative data on ground-water pumping, wastewater return flows, MRGCD diversion data, and other hydrologic information are available;
- The 1971-98 record had sufficient low-flow years to allow construction of an artificial 3-year drought similar to that experienced in the 1950s.

Evaluation of Historical Flows

To validate the use of 1971-98 period for hydrologic baseline, we undertook an evaluation of historical records from selected Rio Grande streamflow gages. The USGS gaging stations at Embudo, Otowi, and San Marcial provide some of the oldest continuous records of streamflow available in the United States — portions of which date to the 1880s. Other gages on the Rio Grande and Rio Chama have records that started in the 1930s or 1940s. In general, there are good coincident records of streamflow from gages in the Otowi-to-San Marcial reach for the period 1943-98. Good records for gages at Embudo, Otowi, and San Marcial are coincident to about 1900. A summary of available streamflow records for key stations on the river, tributaries, and irrigation / flood channels is provided in Appendix C.

The long-term record of annual flows at Otowi (Figure 3-1) shows that river discharge just above Cochiti has averaged 1,518 cfs during the 1900-98 period. Over the pre-SJC importation period of 1900-70, flows at Otowi averaged 1,492 cfs. For the period 1971-98, Otowi flows averaged about 1,585 cfs. As detailed in Appendix B, the 1971-98 period includes imported SJC water at Otowi that averaged 73 cfs. Subtraction of 73 cfs of SJC water from the 1971-98 flows at Otowi results in a mean flow of native water of 1,512 cfs for 1971-98 — within 1 percent of the mean native flow (1,492 cfs) for the 1900-70 period.

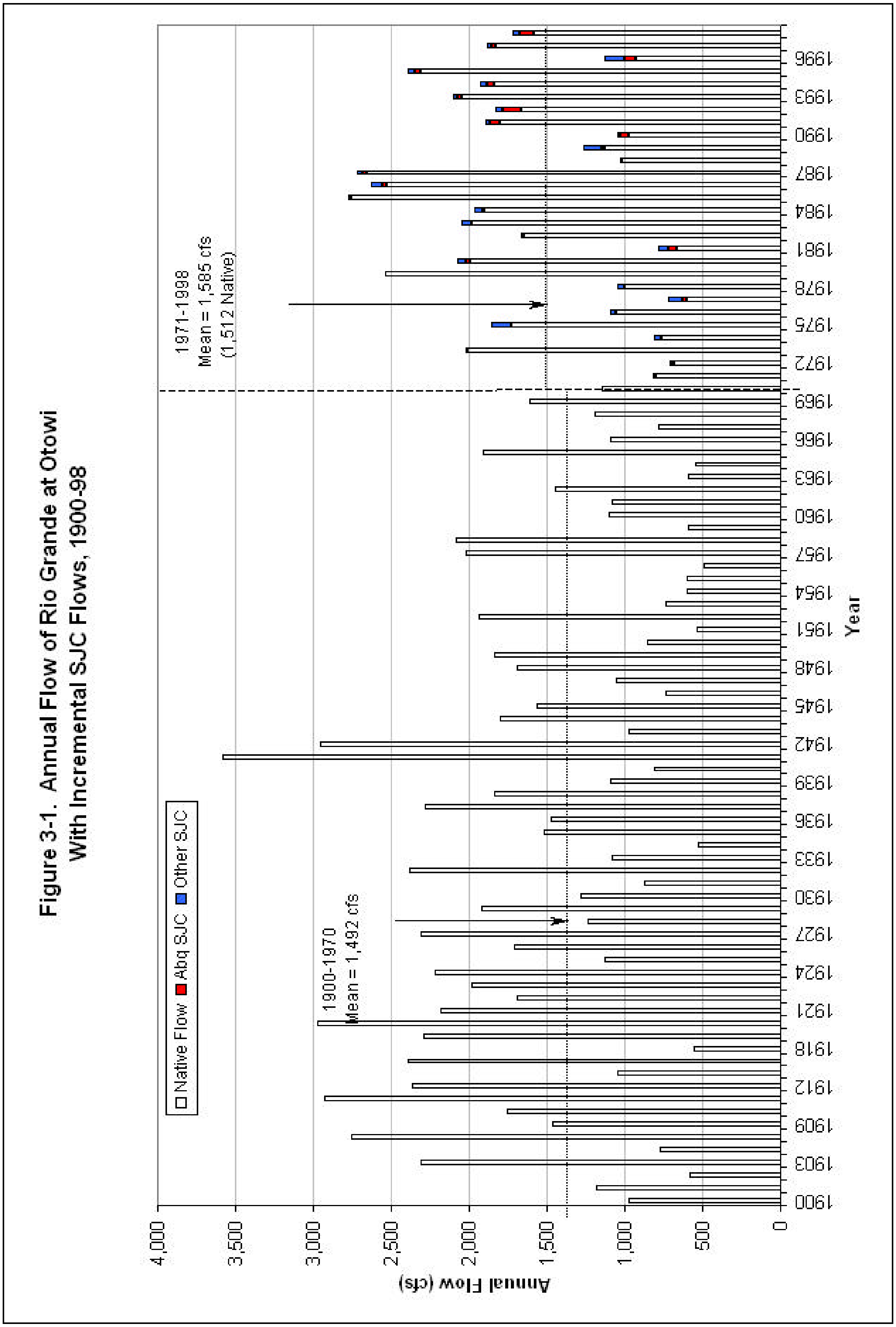


Figure 3-1. Annual Flow of Rio Grande at Otowi With Incremental SJC Flows, 1900-98

It should be noted that by 1900, most of the irrigated development in Colorado and northern New Mexico was already in place. Thus, the 1900-98 record (at least on an annual basis) is reasonably representative of present-day conditions except for the added SJC water. Construction and operation of Abiquiu, Cochiti, and Jemez Reservoirs have undoubtedly had an effect on late summer and early fall river flows (more sustained) and in attenuating spring snowmelt peak flows. However, these reservoirs have had little effect on annual flows. As evidenced by Figure 3-2, there is an excellent correlation between the annual flow sequence for the Otowi and Albuquerque gages over the 1943-98 period. Thus, we reasoned that since the 1971-98 record at Otowi is representative of the last 100 years of flows on the Rio Grande, so is the 1971-98 record at the Albuquerque gage.

The gaged record at Albuquerque (Figure 3-3 and Appendix C) indicates that the river flows at Albuquerque have averaged about 1,410 cfs over the 1971-98 period. Based on our evaluation of SJC water in the Rio Grande since 1971 (Appendix B), approximately 19 cfs (13,494 ac-ft/yr) of this flow on average (and about 32 cfs in the July-October period) has been City SJC water — much of which has been used by the MRGCD for irrigation purposes. (See Appendix B, Table B-5 for a summary of estimated SJC water at Albuquerque and other MRG stream gages.)

What is lacking in the 1971-98 record at Albuquerque is a multi-year drought similar to that which occurred in the 1953-57 period (see Figure 3-1). As discussed subsequently, we inserted a multi-year drought into the 1971-98 hydrologic record at Albuquerque to simulate such a drought and the effects that the No Action and DWP alternatives would have on river flows during such a period.

The seasonal runoff pattern of the Rio Grande at Albuquerque is shown in Figure 3-4. The snowmelt runoff season generally begins in April and proceeds to a peak (typically >3,000 cfs in May or June). After June, streamflow usually declines through July and August and stays below 1,000 cfs (on average) through January before increasing again in March and April.

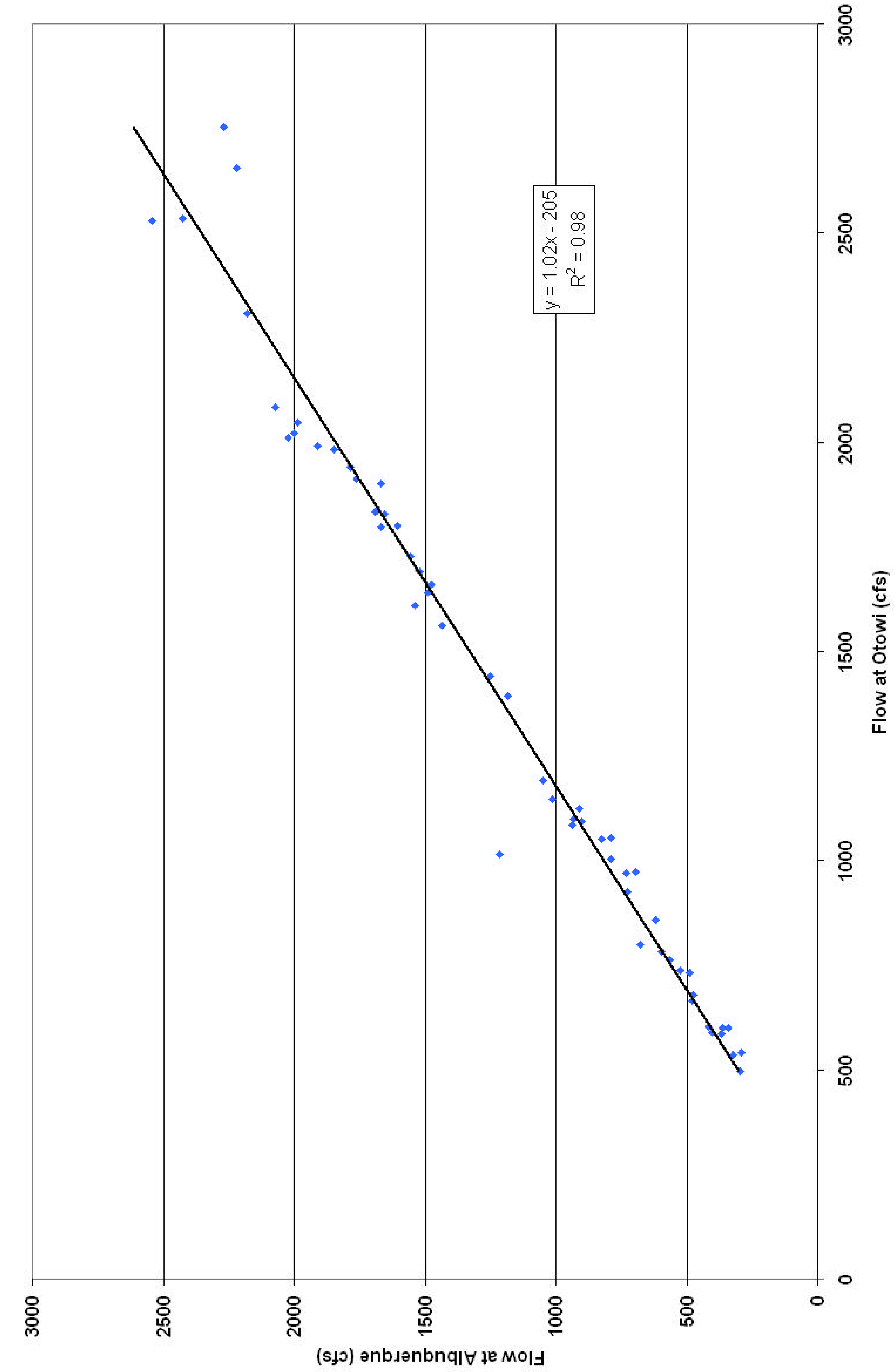
Relationship of Flows Between Gaging Stations

To further examine the 1971-98 record of river flows and its suitability as a hydrologic baseline, the relationship of monthly flows from gaging stations at Otowi, San Felipe, Albuquerque, Bernardo, San Acacia, and San Marcial were compared. The intent was to evaluate the record of monthly flows and the 'apparent losses' (differences in measured flows) between the gages and whether or not there were trends in such losses.

Mean Monthly Flows for 1971-98

Table 3-1 summarizes mean monthly flows for six gaging stations in the MRG basin for the period 1971-98. Flows at three of the stations—Bernardo, San Acacia, and San Marcial—were based on addition of flows in the river channel and the adjacent low-flow conveyance channel (LFCC). At all gages, flows are generally highest in May (snowmelt peak) and lowest in October (prior to the end of irrigation season and after the summer thunderstorm season). Overall, there is a net decrease in measured flow in the downstream direction with one exception. San Acacia generally has more flow than Bernardo because of inflows of the

Figure 3-2. Correlation of Annual Flows, Otowi vs. Albuquerque, 1943-1998



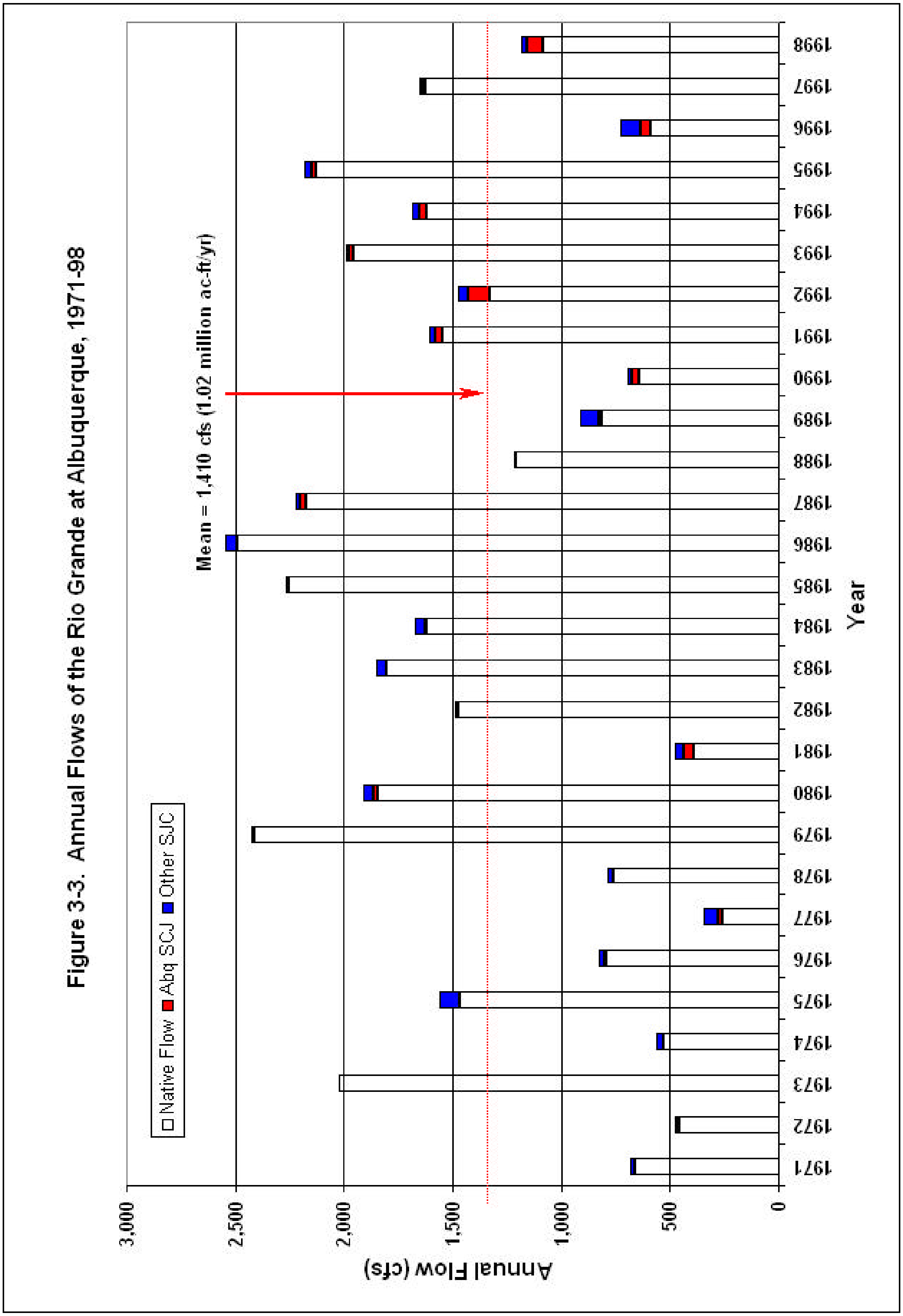


Figure 3-3. Annual Flows of the Rio Grande at Albuquerque, 1971-98

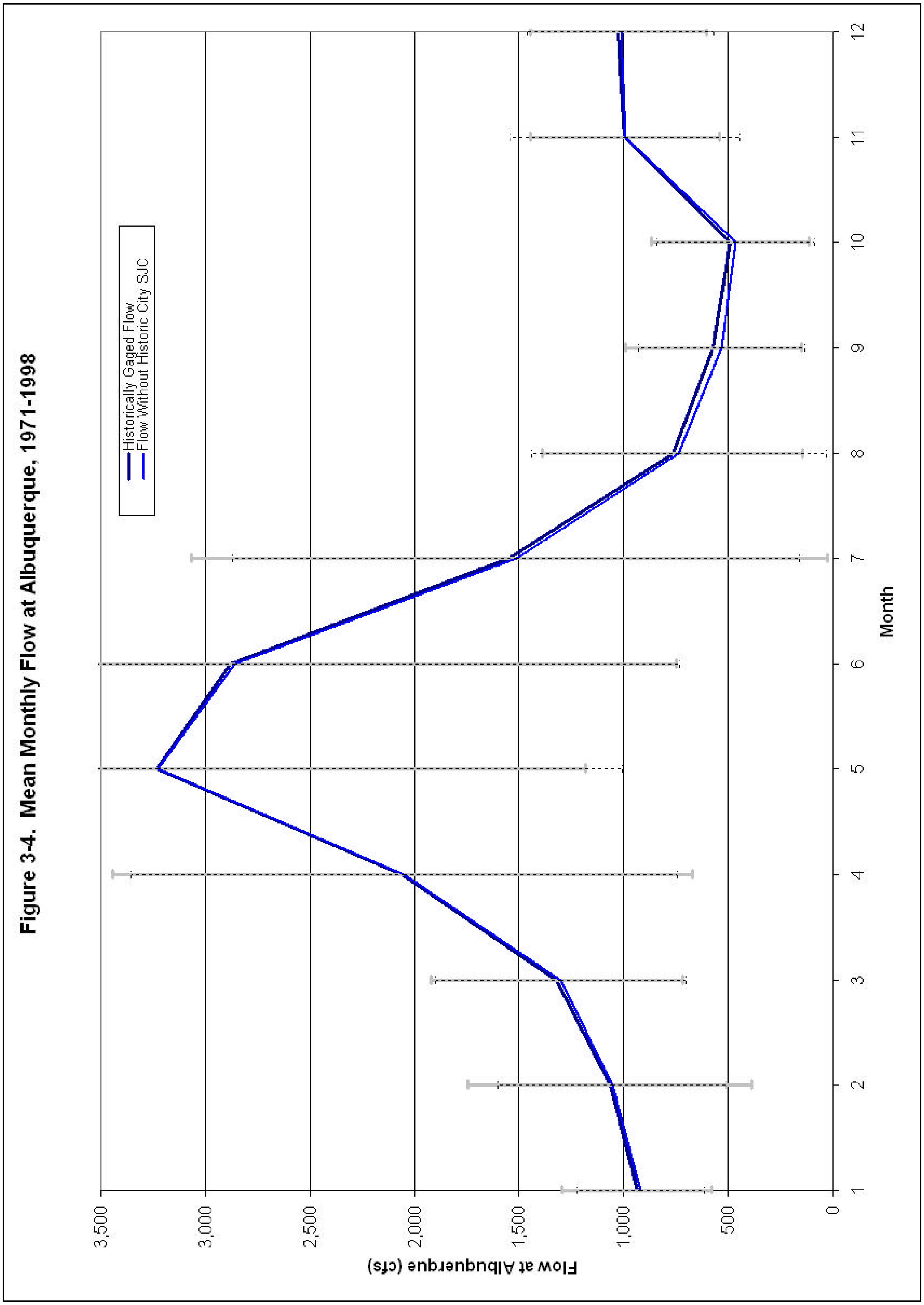


Figure 3-4. Mean Monthly Flow at Albuquerque, 1971-1998

TABLE 3-1
Mean Monthly Flows at Rio Grande Stations, 1971-98

Month	Otowi (cfs)	San Felipe (cfs)	Albuquerque (cfs)	Bernardo (cfs)	San Acacia (cfs)	San Marcial (cfs)
January	824	893	939	971	1,033	998
February	948	1,042	1,060	1,082	1,172	1,121
March	1,403	1,356	1,298	1,152	1,163	1,156
April	2,299	2,110	2,011	1,635	1,625	1,600
May	3,778	3,334	3,230	2,923	2,892	2,739
June	3,354	3,207	2,888	2,620	2,468	2,407
July	1,597	1,882	1,527	1,255	1,284	1,312
August	1,002	1,069	809	575	757	770
September	906	850	590	427	637	606
October	841	740	496	406	495	530
November	983	940	991	1,055	1,142	1,072
December	951	968	1,019	1,047	1,136	1,078
Annual Average	1,574	1,533	1,405	1,262	1,317	1,282

Rio Puerco and Rio Salado (and probably ground-water inflows) between the two gages. Note that numbers in Table 3-1 may differ slightly from those presented in the more detailed summaries in Appendix A and from numbers cited on various figures due to rounding and depending on whether averaging was based on daily or monthly data.

The 'apparent losses' between gaging stations for 1971-98 are as follows:

- Otowi to San Felipe 41 cfs
- San Felipe to Albuquerque 128 cfs
- Albuquerque to Bernardo 143 cfs
- Bernardo to San Acacia -55 cfs (gain from ground water and tributary inflows)
- San Acacia to San Marcial 35 cfs

An analysis was performed on the 1971-98 streamflow record for the above gaging stations to examine whether there was a trend in 'apparent losses' between upstream and downstream stations in Table 3-1. Results, based on graphical and statistical inspections of the records, indicated no trends. Thus, the above summary of 'apparent losses' between Otowi and San Marcial and between individual stations for the 1971-98 period suggests a relative stability in the total consumption of water by irrigation, riparian vegetation, water surface evaporation and/or losses to deep seepage to the ground-water system.

Although the 1971-98 period shows a stable relation of flows between gaging stations, a previous analysis (CH2M HILL, 1999a) suggested that the total conveyance of water to San Marcial from Otowi has become perhaps 10 percent more efficient over the 1971-98 period as compared to the 1943-70 period. This is probably attributable to improved conveyance management and the presence of the LFCC, which even though not receiving direct river diversions since 1985, has acted to intercept seepage from the main channel (floodway) and convey it past San Marcial more efficiently than would have otherwise occurred. Another factor making downstream conveyance more efficient in recent decades is the channelization projects completed in the 1960s and 1970s by the Corps. Such projects have tended to shorten channel length and retard formation of oxbows and meanders.

Section 4

Hydrologic Baseline and Operating Assumptions for the No Action and DWP Alternatives

SECTION 4

Hydrologic Baseline and Operating Assumptions for the No Action and DWP Alternatives

To evaluate the hydrologic effects of the DWP alternative and compare them to effects caused by the No Action alternative, it is necessary to define operations under both alternatives, and their associated hydrologic assumptions and conditions. As explained below, the use of an 'adjusted' 1971-98 hydrologic record, coupled with projected water demands, forms the basis for simulating and comparing the hydrologic effects under each alternative over the period 2006-60.

No Action

The No Action water supply alternative for the City basically consists of a continuation of ground-water pumping into the foreseeable future. As discussed in Sections 5 and 6, such pumpage will result in increasing quantities of river water seeping into the Albuquerque basin aquifer and substantial amounts of water removed from aquifer storage (with attendant large water-level drawdowns). From a water rights perspective, the net effect of the increased river seepage (despite increased return flows at the SWRP at Rio Bravo) will be a loss of flow in the river in the Albuquerque reach.

Under the No Action alternative, City wells would withdraw water from the Albuquerque basin aquifer for almost all municipal and industrial needs through the year 2060 –- with the following exceptions:

- Up to 3,000 ac-ft/yr of City SJC water would be used for the Nonpotable Surface Water Reclamation Project (CH2M HILL, 2000a) recently permitted by the OSE. This water would be released from storage in Abiquiu Reservoir and diverted via a subsurface collection facility on the Rio Grande just downstream of Alameda Bridge.
- The provision of City SJC water to honor existing contractual lease agreements with other entities amounts to about 2,600 ac-ft/yr through 2011. After 2011, the lease agreements would expire and no further releases of SJC water would be made for this purpose.

Although only the limited quantities of City SJC water listed above are assumed to be in the Rio Grande below Abiquiu Reservoir, No Action does assume that the City's SJC allotment of 48,200 ac-ft/yr is taken from Heron Reservoir each year. But because the timing, amounts, and ultimate uses for the City's allotted SJC water (other than the listed quantities) cannot be predicted, the hydrologic evaluation and modeling analyses presented herein address only the amounts specified above.

In effect, the No Action alternative represents what the City would need to do if the DWP project is not constructed. Or, in other words, how the City would attempt to meet customer water demands if the project to use its SJC water cannot be built. No Action assumes that the City's conservation plan is fully implemented as scheduled (i.e., 40 percent reduction in average demand from 250 to 150 gallons per capita per day over the period 1995 to 2015).

The No Action hydrologic baseline was developed in the following three steps:

1. Adjust the 1971-98 gaged streamflow record by removing historic City SJC water from the record (see Appendix B for summary of historical City SJC water).

2. Subtract from the adjusted 1971-1998 streamflow record the effects of historical City ground-water pumping and the effects of SWRP returns on river flows. This is based on running the OSE interim ground-water model to estimate historical pumping-induced river seepage and using the City's record of wastewater return flows.

3. Subtract or add to the flows determined in step 2 the projected future effects (2006 through 2060) of continued, full-scale, ground-water pumpage (using the OSE interim model) and SWRP return flows on river flows. Also, included in the baseline are: variable SJC releases made for existing City leases (up to about 2,600 ac-ft / yr) through termination in about 2011 and approximately 3,000 ac-ft / yr in SJC releases for the City's Nonpotable Surface Water Reclamation Project (through 2060); see Table E-1, Appendix E).

DWP Alternative

As discussed previously, the three DWP diversion alternatives are a modified surface diversion at the existing Angostura diversion dam, a new surface diversion in the vicinity of the Paseo del Norte Bridge, and a subsurface collector facility spread over a 1.5-mile reach of river both north and south of the Paseo del Norte Bridge. In a normal year of DWP operation, each of these alternatives would divert a total of 94,000 ac-ft / yr (or 130 cfs on a continuous basis) from the river, with about 47,000 ac-ft / yr (or 65 cfs) returned to the river at the SWRP below Rio Bravo Bridge. The most significant difference among the three DWP alternatives is the length of river that is affected (or depleted) with respect to Rio Grande flow. In the case of the Angostura alternative, the affected reach is about 32 miles – and some 14 miles for the new surface or subsurface collector facility near Paseo del Norte. (Note that under the No Action alternative there is also a depleted reach through the Albuquerque area due to the effects of pumping on river flows; see subsequent discussion in Section 5.)

The DWP hydrologic baseline was developed in the following steps:

1. Adjust the 1971-98 gaged streamflow data by removing historic City SJC water from the record (see Appendix B for summary of historic City SJC water).

2. Subtract or add to the adjusted record developed in step 1 the effects of historical City ground-water pumping and SWRP returns on river flows.

3. Subtract or add to step 2 flows the projected future effects (2006 through 2060) of the reduced level of ground-water pumpage (i.e., less than No Action effects) as calculated by the OSE interim model and SWRP return flows on river flows.

4. Add or subtract from item 3 flows the proposed release and diversion amounts for the DWP alternative. Again, in a normal year this will involve the constant release of about 66 cfs from the City SJC pool in Abiquiu Reservoir (reduced to about 65 cfs at Albuquerque after conveyance losses) and a constant diversion of about 130 cfs, half of which is returned at the SWRP. As was the case for No Action, included in the DWP simulation are: SJC releases made for existing City leases (up to about 2,600 ac-ft/yr in some years) through termination in about 2011, and approximately 3,000 ac-ft/yr in SJC releases for the City's Nonpotable Surface Water Reclamation Project through 2060; see Table E-2, Appendix E.

General Operating Plan for DWP Diversions

As has been the case since the inception of the SJC project in 1971, under the DWP the City will continue to work closely with those agencies having responsibility in managing the flows of the Rio Grande and Rio Chama. These include the USBR, the Corps, the OSE, and the MRGCD. More recently, because of the critical habitat designation for the Rio Grande silvery minnow, the U.S. Fish and Wildlife Service has become a more active player in flow management on the river. With the evolution of the multi-agency sponsored Upper Rio Grande Water Operations Model (URGWOM), and continued conference calls and meetings during critical times of year, the management of the SJC project and river flows and reservoirs on the Rio Chama and Rio Grande should become more efficient.

The City, in concert with the above agencies, will monitor snowpack, reservoir storage, seasonal weather forecasts, and other factors – particularly in the late-winter and early spring-periods leading up to the irrigation season (which begins in March). Preliminary decisions and action plans will be formulated as to how the City's SJC water will be managed, particularly in the case of likely low-flow or drought conditions, and whether or not surface diversions under the DWP will be curtailed or shut down entirely for several months in the coming year. As the critical warm weather irrigation season approaches (usually beginning in April or May), flow forecasts and river management decisions will be updated using URGWOM and specific plans formulated relative to the City's DWP release and diversion program for the coming year.

Objective and Conservative Basis for Evaluation of Hydrologic Effects Caused by DWP Diversions

To provide for an objective evaluation of hydrologic effects on the Rio Chama and Rio Grande through Albuquerque and down river, it is necessary to specify specific values of flow, release, and diversion under a hypothetical operation of the DWP. The release-diversion scenarios described below are intended for that purpose, and represent a worst-case condition for evaluation under the EIS or OSE Permit No. 4830. Deviations from the simplified release-diversion plan (which are fully anticipated under active management on the Rio Grande), will result in hydrologic effects less than those estimated in this document.

Diversion in Vicinity of Paseo del Norte Bridge

Figure 4-1 provides a simplified overview of how the DWP will be operated in most years assuming a diversion (either by surface or subsurface diversion) in the vicinity of Paseo del Norte Bridge. A constant release of about 66 cfs of City SJC water will be made from Abiquiu Reservoir. After incurring conveyance losses between Abiquiu and Albuquerque, approximately 65 cfs of SJC water will reach the diversion facilities. There a constant diversion of 130 cfs will occur throughout the year provided flows are more than or equal to a specified 'threshold flow' of 260 cfs just above the diversion point. The 130-cfs DWP diversion will include 65 cfs of SJC water and 65 cfs of Rio Grande water. The 65 cfs of SJC water will be consumptively used within the City's Water Service Area (WSA). The 65 cfs of Rio Grande water will, in effect, be returned to the river at the SWRP outfall near Rio Bravo.

Under the above plan, and assuming a diversion near Paseo del Norte (either surface or subsurface), there will be a reach of the Rio Grande between the point of diversion and point of return flow (about 14 miles) that will be depleted relative to native flows. (As shown subsequently in Section 5, the No Action alternative has a similar effect in terms of depletion.) To ensure that DWP diversions do not dry up or otherwise adversely affect the riverine ecology between the diversion and return flow points, the City proposes to implement a curtailment strategy as described below.

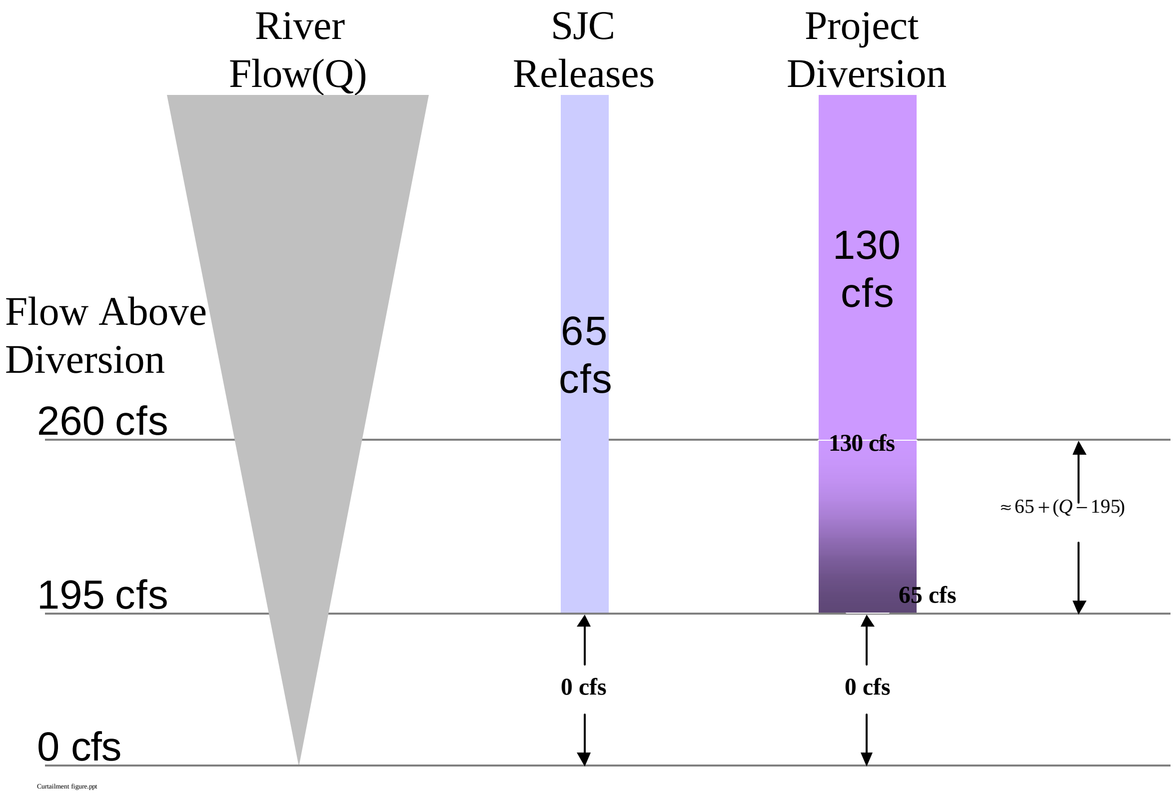
For "normal" operation of the DWP under a constant release-diversion scenario, the flow at the diversion point (assumed here to be just north of the Paseo del Norte Bridge) must be 260 cfs or more based on the following:

- A diversion rate of 130 cfs comprised of 65 cfs of SJC water and 65 cfs of native water
- A fishway bypass flow of 50 cfs on the west side of the river
- A flow of 20 cfs at the outlet of the sluiceway on the east side of the river to provide for downstream movement of sediment and fish past the intake screens
- A minimum flow of 60 cfs over or through the adjustable crest-gate dam

Therefore, under "normal" operation, the minimum flow bypassing the DWP diversion will be 130 cfs (50 + 20 + 60 = 130 cfs), which is considered sufficient to prevent river drying in the Albuquerque reach, based on observations made in 2002.

Thus, the 260-cfs flow above the dam becomes a curtailment threshold intended to ensure that the Albuquerque reach (diversion to SWRP) will remain wet when the DWP is in operation. This curtailment threshold allows for potential depletions over the Albuquerque reach and ignores any inflows that would potentially vary during low-flow conditions.

Under "curtailment" operation, when native river flows at the diversion point fall below 195 cfs (total flow of 260 cfs with 65 cfs SJC in the river), the City will begin curtailing the quantity of the diversion by 1 cfs for each cfs of decrease in native flow, but will continue to release and divert the full 65 cfs of SJC water. As native flow continues to drop, DWP diversions will be reduced accordingly. When native flow reaches 130 cfs above the diversion, DWP diversions will cease entirely.



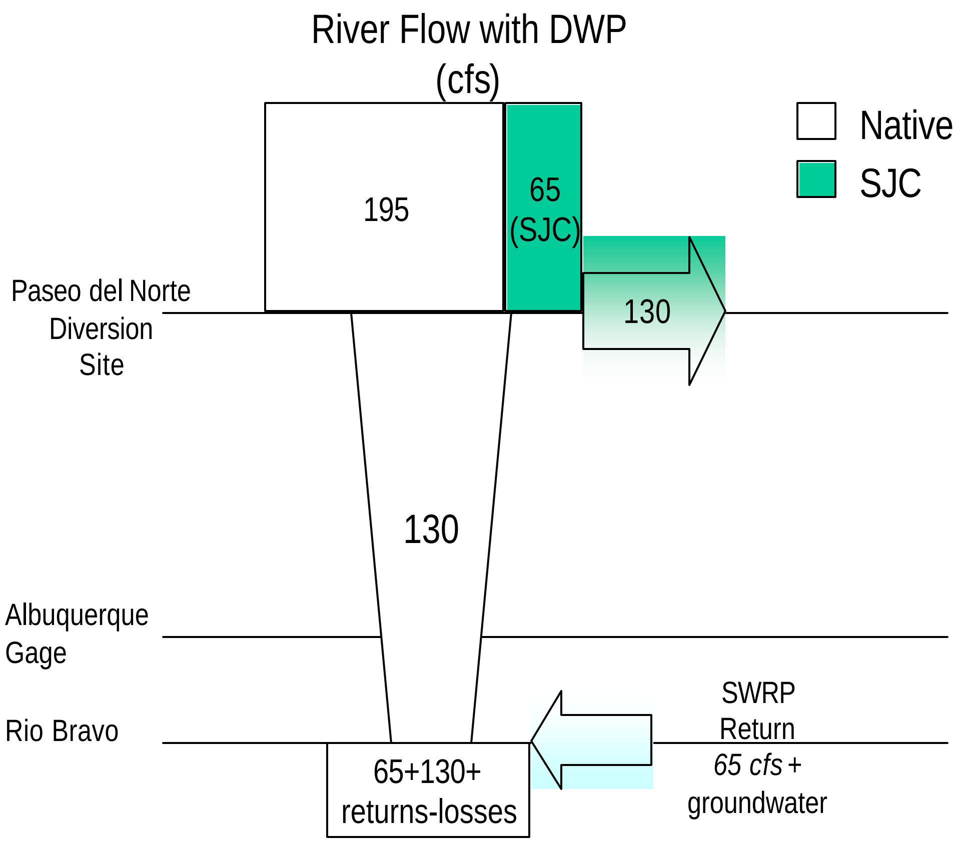


Figure 4-1. Summary of Release/Diversion Scenario for DWP and Relation to River Flows Assuming Diversion Near Paseo del Norte Bridge

The actual quantity of diversion would be based on the equation shown in Figure 4-1. From the diversion dam to the SWRP return flow point, minimum flows will be about 130 cfs, minus seepage and evapotranspiration losses plus any gains due to returns, thereupon increased by the amount of the return flow at the SWRP.

During periods of curtailment, the City will provide increasing amounts of water to the WSA from wells. During periods of complete shut down of river diversion, the WSA will be supplied entirely from wells.

Diversion at the Existing Angostura Diversion Dam

Figure 4-2 depicts the DWP release/diversion scenario assuming that the diversion points were at Angostura rather than at Paseo del Norte. In this case we estimate a threshold flow of about 310 cfs (after MRGCD diversions for irrigation) at the diversion and a curtailment strategy similar to that described above for the Paseo del Norte diversion point.

Operations During Initial Years of the Project

When the DWP begins operation in 2006, there will still be a lingering effect of historical City pumping on the river. In other words, the City's past pumping has lowered the water table in the aquifer inducing continued seepage of native Rio Grande water into the adjacent aquifer. The effects of this additional seepage will continue for about a decade. In accordance with the conditions on the City's existing ground-water permits under No Action and the *Guidelines for Review of Water Right Applications in the Middle Rio Grande Administrative Area*, the City must offset both current and historical pumping effects. The City will meet these conditions by releasing City SJC water stored in Abiquiu. The estimated total water needed to offset the residual pumping effects, as calculated using the OSE interim model, for the period from 2006 to 2017 is about 102,000 ac-ft (see Table E-2). This quantity is obtained by summing the estimated annual release amounts and does not account for storage losses in Abiquiu. Accounting for seepage and evaporative losses, the estimated quantity of City SJC water needed in storage to offset the residual pumping effects and fully implement the DWP, including up to 3,000 ac-ft/yr of SJC for the Nonpotable Surface Water Reclamation Project, is on the order of 167,000 ac-ft or more, as described below.

At the end of 2002, the USBR indicated that the City had approximately 31,000 ac-ft of SJC water remaining in Abiquiu. For the years 2003 through 2005, the City's annual allotment of SJC water totals 144,600 ac-ft (approximately 136,000 after evaporative losses for storage to 2006). The total amount of water available in 2006 in Abiquiu will be essentially equal to the amount necessary to fully implement the project as illustrated in Table 4-1.

Part of the reason for the 102,000 ac-ft offset required over the 2006-16 period relates to the fact that not as much ground water will be returned to the river via the SWRP outfall as previously returned. Thus, the residual pumping effects and the lower ground-water return

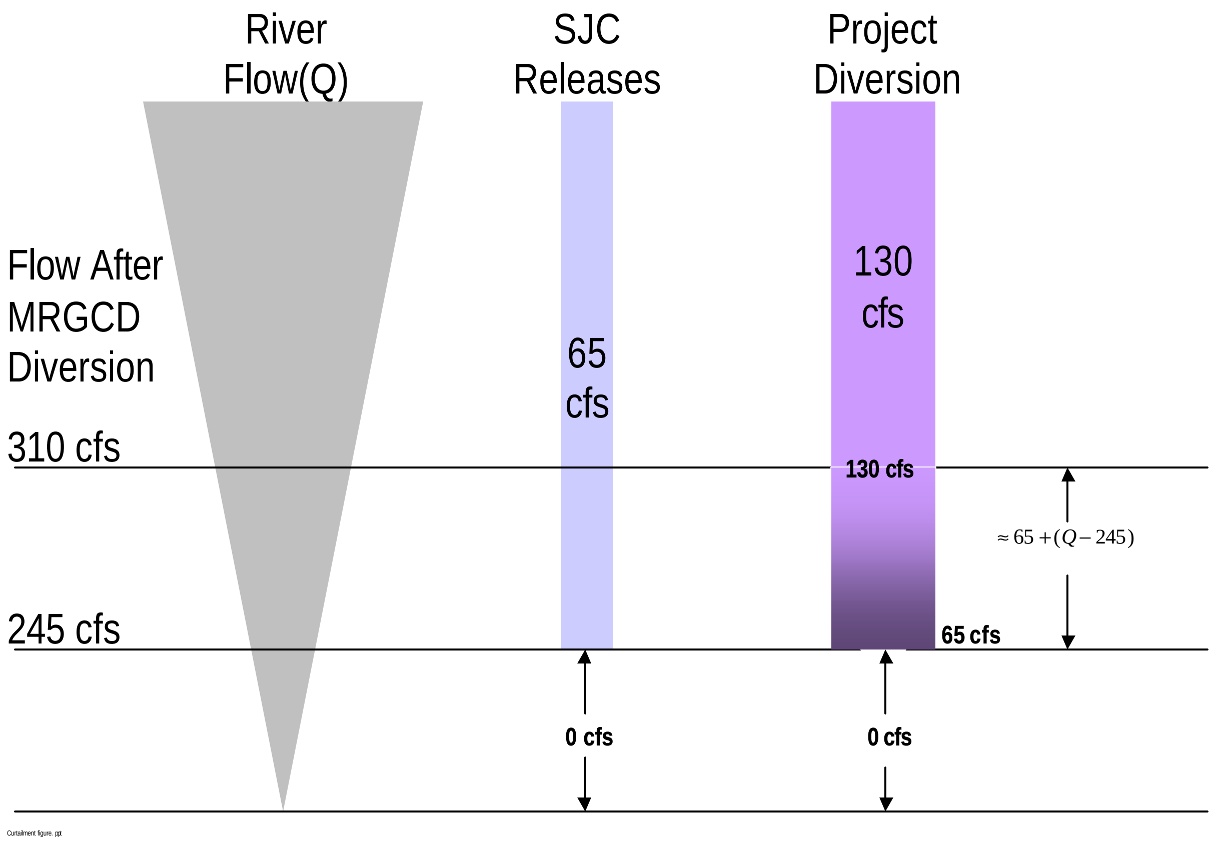


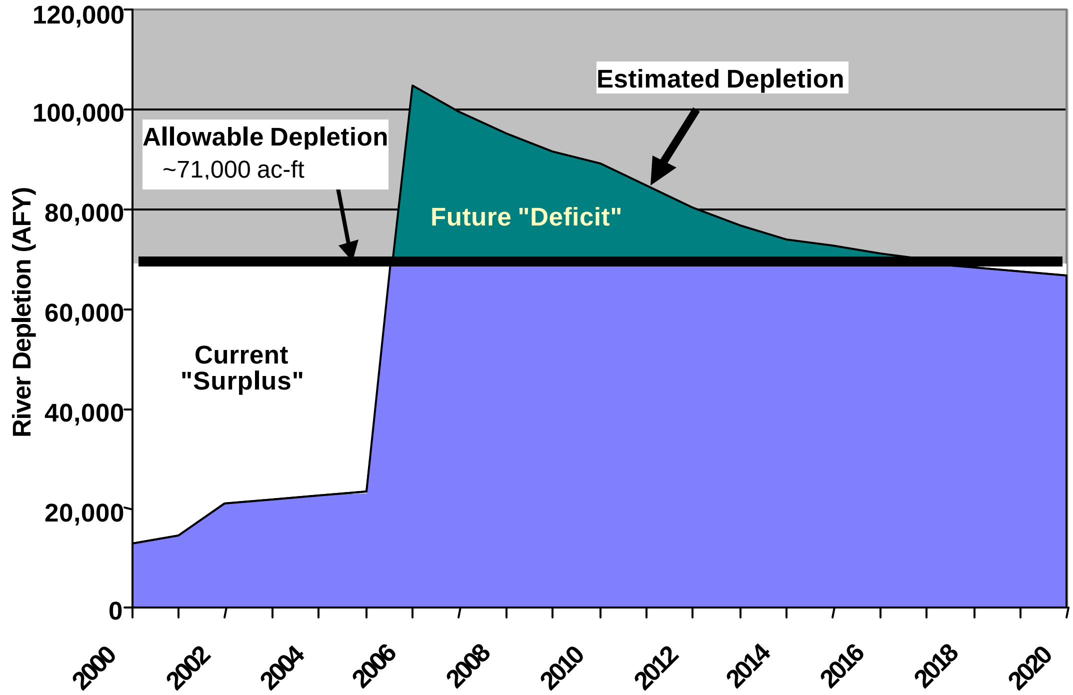
Figure 4-2. Summary of Release/Diversion Scenario for DWP and Relation to River Flows Assuming Diversion at Angostura Diversion Dam Above Bernalillo

TABLE 4-1
Summary of City SJC Water Needed and Potentially Available for Full Operation During the Initial Years of the Project

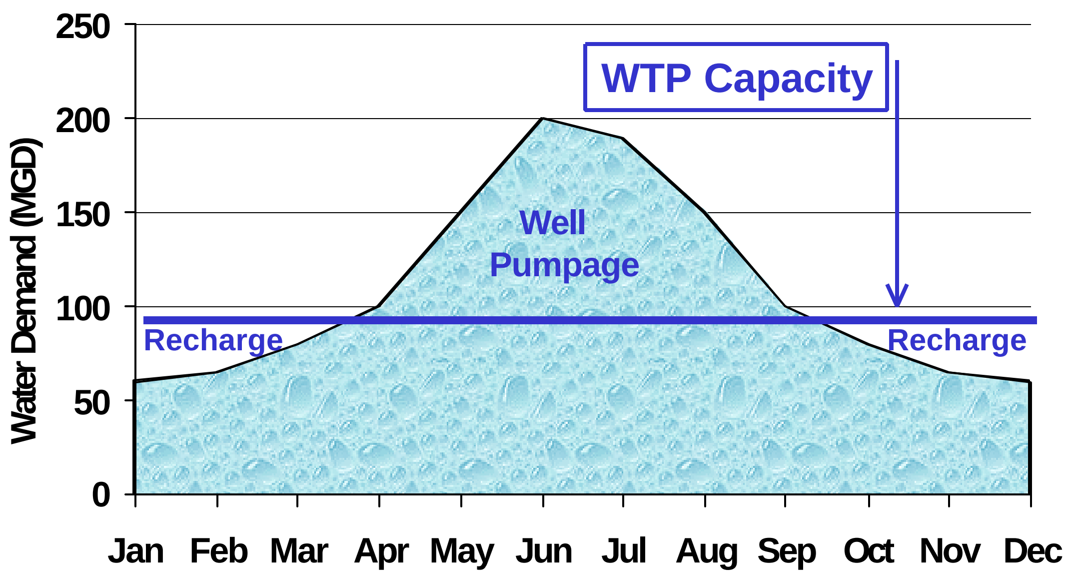
1.	**AMOUNT REQUIRED** – ***Amount of City SJC Water Needed in Storage at the End of 2005 to Fully Implement the DWP Through 2017 and Provide Required OSE Offsets***.	
	Amount Needed to Offset Residual Pumping Effects, 2006-2017	102,000 ac-ft
	Amount Needed for North I-25 Project Releases, 2006-2017	30,000 ac-ft
	Amount Needed to Offset Abiquiu Evaporation and Seepage Losses, 2006-2017	35,000 ac-ft
	Total City SJC Water Needed in Abiquiu	**167,000 ac-ft**
2.	**AMOUNT AVAILABLE** - ***Amount of City SJC Water Available for Storage 2003 Through 2005***	
	Estimated 2002 Year-End Storage of City SJC Water In Abiquiu	31,000 ac-ft
	Allotment of City SJC 2003-2005 (3 x 48,200 ac-ft)	144,600 ac-ft
	Total City SJC Water Available for Storage	**175,600 ac-ft**
	Amount Needed for North I-25 Project Releases 2003–2005	4,100 ac-ft
	Amount Needed to Offset Abiquiu Evaporation and Seepage Losses 2003-2005	8,000 ac-ft
	Net City SJC Water Available for Storage in Abiquiu	**163,500 ac-ft**

will combine to make a water rights deficit of 20,000± ac-ft in early DWP years (shown as Future "Deficit" in Figure 4-3 (a)). The City will mitigate this deficit with additional (or supplemental) releases of SJC water (again, some 102,000 ac-ft in total) from storage in Abiquiu Reservoir during the first decade of the project (as indicated in Table 4-1) and through use of its vested and acquired water rights. As the effects of historical City pumping on the river are dissipated, and under much reduced levels of pumping under the DWP, the seepage rate and deficit will decline such that additional releases of SJC will no longer be needed after about 2017 (see Table E-2, Appendix E).

Besides the additional releases of SJC in early project years, the DWP also will have an aquifer storage and recovery (ASR) component. Details of ASR operation, including an operating permit from OSE, have yet to be worked out. However, the general scheme in Figure 4-3(b) shows how the proposed ASR will be operated on a seasonal basis. The Chappell WTP will operate at an essentially constant rate of 84 mgd or 130 cfs. Peak summer demands, which are considerably higher than WTP capacity (shown at 200 mgd as representative of about 2006 or 2007 in Figure 4-3(b)) would be met with City well pumpage. During low-demand periods, typically October through March, the WTP would be producing sufficient water to allow the wells to be turned off. During this period, recharge would be affected by injection into City wells. The water available for recharge would be highest (about 10,000 to 15,000 ac-ft/yr) during early project years, and gradually decline to zero in later years. The amounts of water involved, number of recharge wells, and other aspects of the ASR program are currently (August 2003) under development.



(a) Summary of DWP Water Balance with Future Deficit Year Depletions Made Up With Extra Release of City SJC from Storage



(b) Under DWP, City Wells will be Turned On in Warm Months to Meet Peak Demands and Turned Off and Used for Aquifer Recharge in Cool Months

Figure 4-3. Summary of DWP Water Balance In Early Project Years and Seasonal Scheme for Well Pumpage, Recharge, and Surface Diversion

Section 5

Effects of No Action and DWP Alternatives on River Flows

SECTION 5

Effects of No Action and DWP Alternatives on River Flows

Evaluation Approach—Coupling the OSE Interim Model with the 1971-98 Adjusted Flow Record

Based on the adjusted hydrologic baseline used for the 1971-98 period described in Section 4, monthly river flows were developed for the No Action and DWP alternatives at the following gaging sites between Cochiti Reservoir and San Marcial on the Rio Grande:

- San Felipe
- Albuquerque
- Isleta
- San Acacia
- San Marcial

As mentioned previously, the Isleta flows are estimated (i.e., flows are not actually gaged at this location) and based on development of a record with additions and subtractions to the 1971-98 gaged record at Albuquerque. These additions and subtractions include those made for SJC releases (see Appendix D for discussion of SJC loss factors used), DWP diversions, river effects (leakage to the aquifer) due to City ground-water pumping, wastewater returns at the SWRP outfall below Rio Bravo Bridge, and an assumption of MRGCD drain return flows of about 220 cfs above the Isleta diversion dam. Such return flows are, in fact, variable from month to month and year to year, but have been assumed as 220 cfs for purposes of consistency in this analysis.

Essentially, the approach for evaluating the effects of the No Action and DWP alternatives on Rio Grande flows involved coupling of the OSE interim ground-water model with the hydrologic baseline of river flows for the 1971-98 period described in Section 4.

The OSE interim model is integrated with a number of output processing tools and spreadsheets as described in detail in CD_README.doc, distributed as part of the CD ROM titled *City of Albuquerque Data Distribution for OSE Diversion Permit Application No. 4830*. In general, OSE model results of predicted aquifer head and predicted inflow to the aquifer from the surface water system (OSE river effects) are used to examine the total drawdown from pre-development and the City's portion of predicted river effects, respectively.

The OSE interim model was used to simulate the effects of future pumping on river flows (i.e., pumpage induces leakage from the river, which reduces river flows through the Albuquerque reach). The changes in leakage estimated by the OSE interim model were used to adjust the Albuquerque gage record as a basis for comparison of flows under the No Action and DWP alternatives over the 2006-60 simulated period.

The OSE interim model utilizes an annual time step whereas the baseline river flows are monthly. Although City pumpage varies monthly, the effects of pumpage on river leakage are delayed and tend to be relatively constant over the year. Thus, the annual estimates of leakage generated by the interim model were assumed to occur evenly in 12 increments from which subtractions could be made from the baseline of monthly streamflow values.

With the pumping-induced adjustments and future return flows input into the 1971-98 baseline flow data, the basic approach was to align the first year's adjusted flow record (1971) with the anticipated DWP starting year 2006, then put 1972 as 2007, ... 1985 as 2020, etc. A 3-year drought was inserted (based on 3-1972s) as future years 2024, 2025, and 2026. The adjusted 1971-98 record was repeated again beginning in 2034 (i.e., 1971 became 2034, 1972 was 2035, and 1985 was 2048, etc.). The 3-year drought was not repeated in the second array.

Comparison of flows for the No Action and DWP alternatives was then completed for the 2006-60 period as a whole and for dry, normal, and extended drought conditions.

Effects at Gaged Sites, 2006 to2060

Figures 5-1(a - e) depict hydrographs of No Action and DWP effects at five sites on the Rio Grande between San Felipe and San Marcial over the entire 2006-60 period. At the graphical scale used, there is no discernable difference between No Action and DWP flows for the simulated period of 2006 to 2060. Comparison of summary statistics in Appendix D suggests that average DWP flows over the 2006-60 period are essentially identical to No Action flows for all stations downstream of Albuquerque. At Albuquerque where the gage is in the temporary 'depleted reach' between Paseo del Norte and Rio Bravo, DWP flows are, on average, 22 cfs less than No Action flows (see Figure 5-2 and Tables D-2 and D-4 in Appendix D). Above Albuquerque at San Felipe and Cochiti, DWP flows are generally 65 cfs higher than No Action flows owing to the SJC releases from Abiquiu.

To examine hydrologic effects in more detail, we focused on differences in flow caused by the No Action and DWP alternatives in terms of the low-flow thresholds described previously in Section 4. The full operation of the DWP alternative for a diversion near Paseo del Norte will require a flow of 260 cfs (195 cfs native and 65 cfs SJC) at the diversion point above the Paseo del Norte Bridge. A flow of 260 cfs at the diversion point is 'historically equivalent' to a flow of about 195 cfs at the Albuquerque gage. As shown in Appendix C and Figure 5-2, a flow of 195 cfs is considerably less than the mean monthly low for the 1971-98 period of 492 cfs.

Figure 5-1a - Hydrograph for Rio Grande at San Felipe - 2006-2060

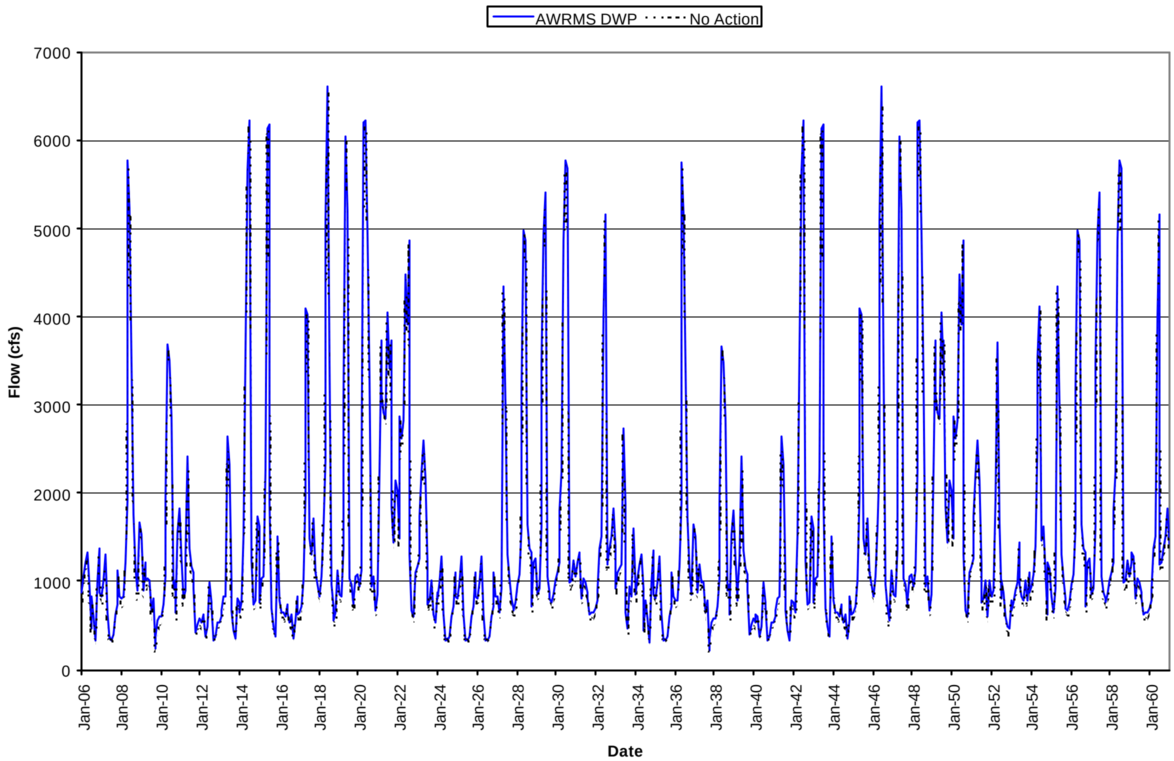


Figure 5-1b - Hydrograph for Rio Grande at Albuquerque - 2006-2060

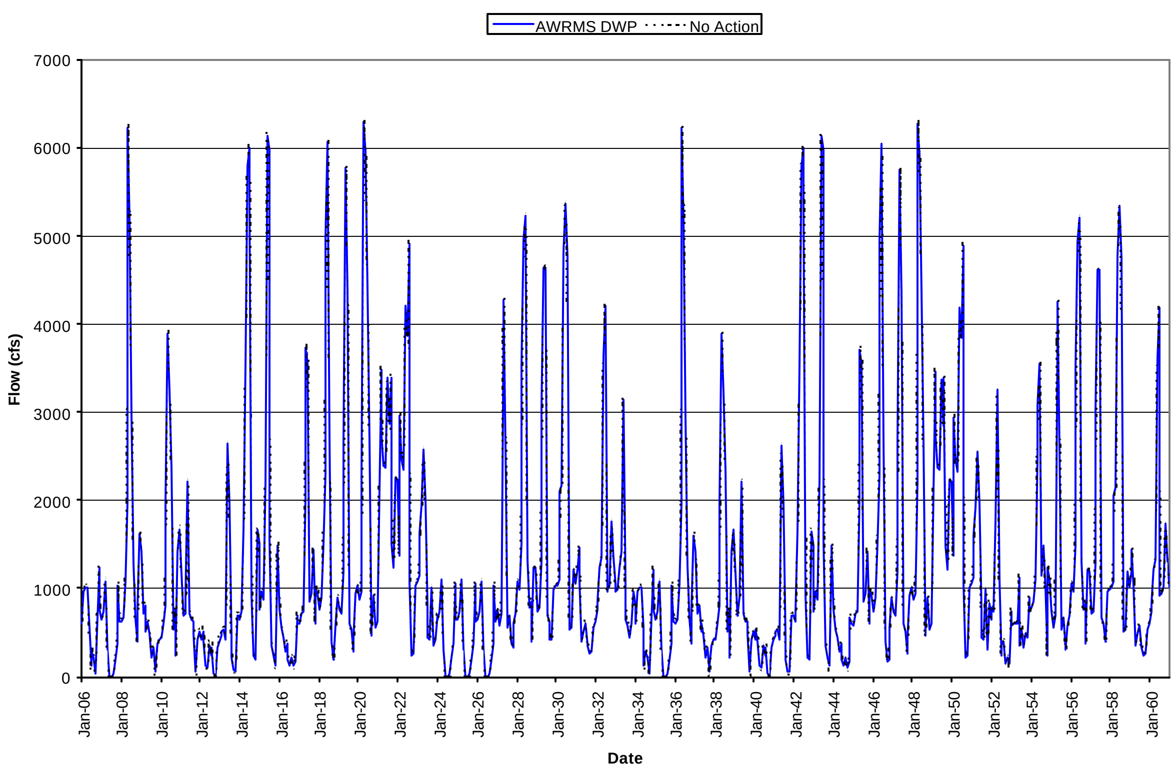


Figure 5-1c - Hydrograph for Rio Grande at Isleta - 2006-2060

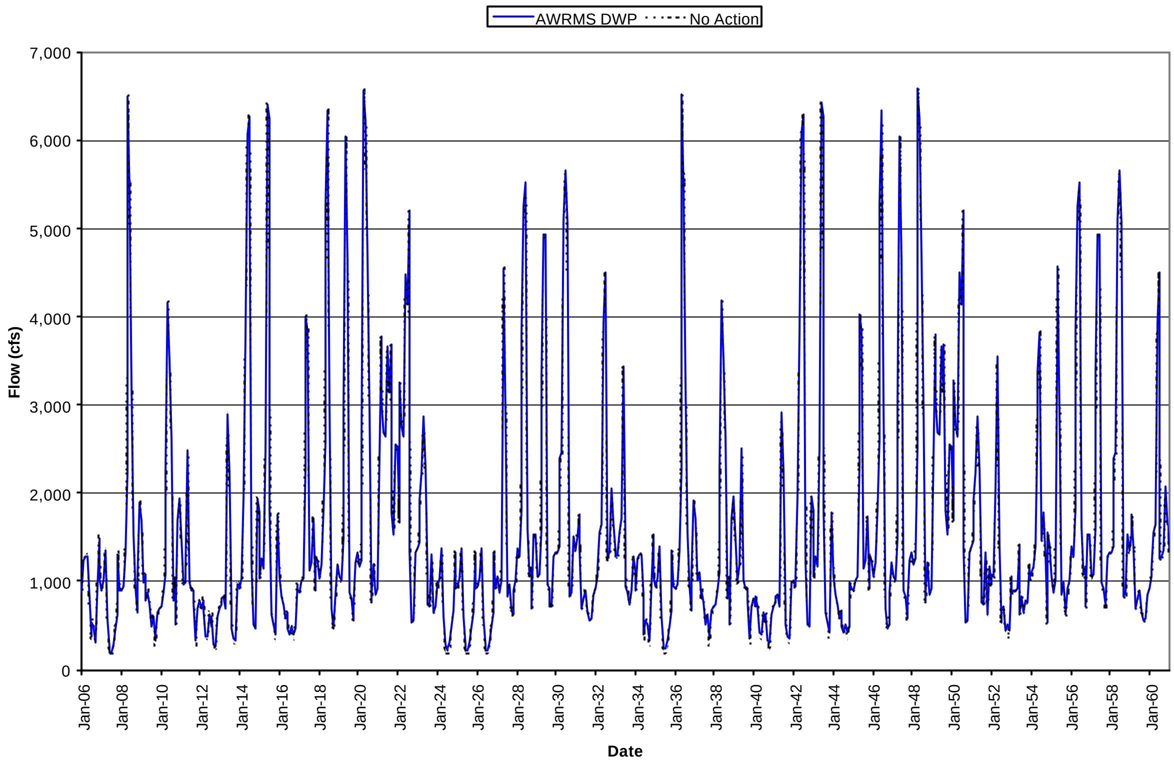


Figure 5-1d - Hydrograph for Rio Grande at San Acacia - 2006-2060

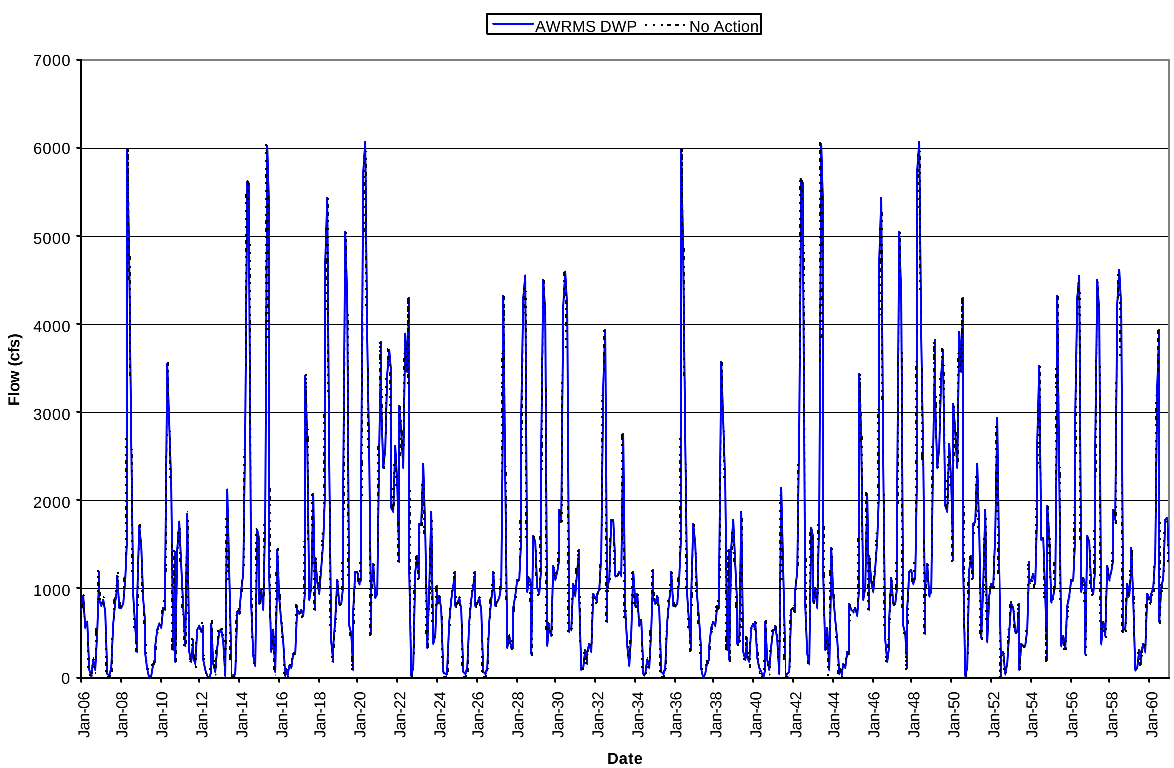


Figure 5-1e - Hydrograph for Rio Grande at San Marcial - 2006-2060

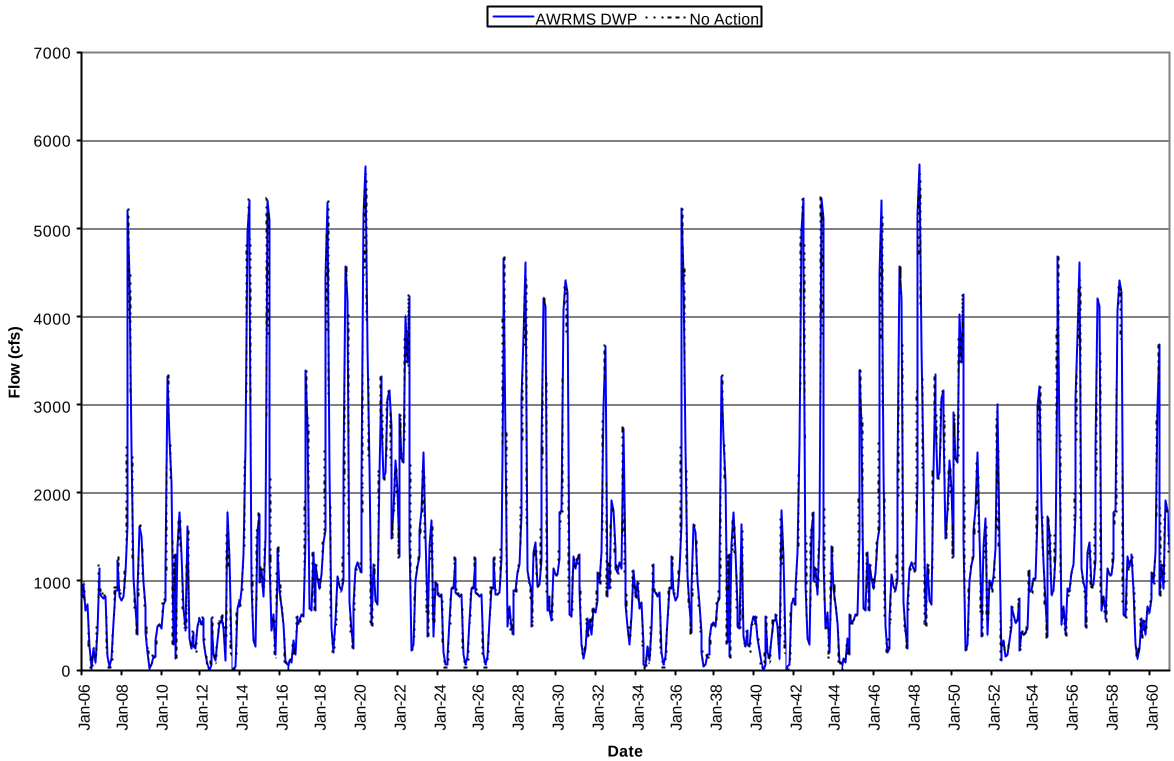
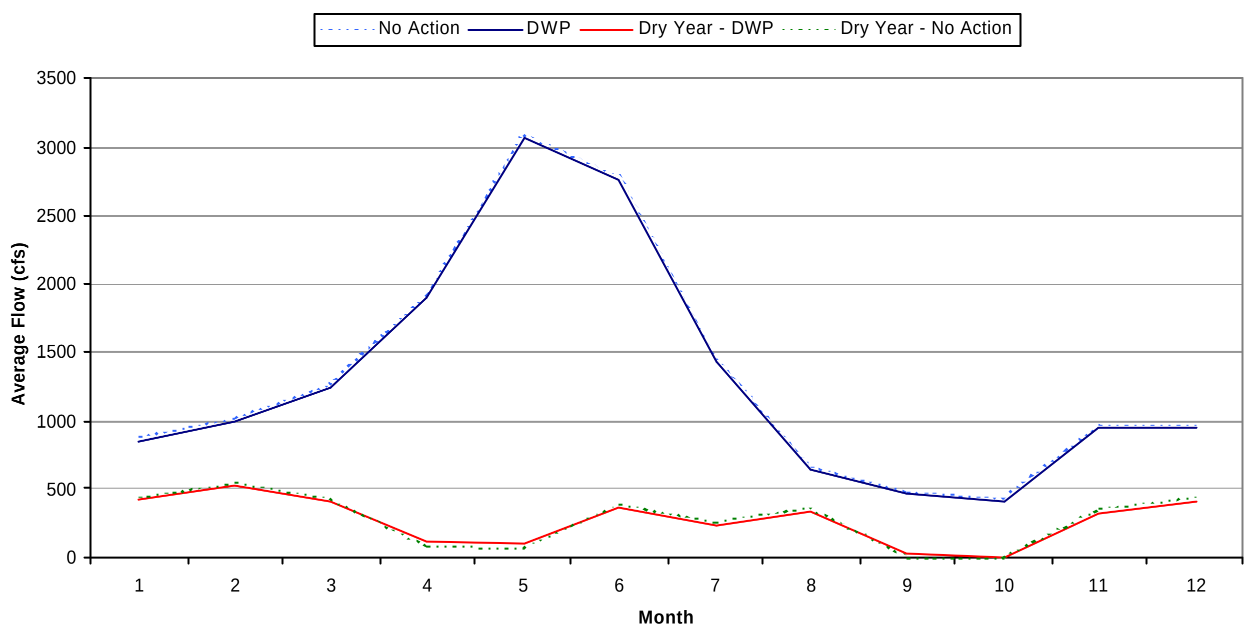


Figure 5-2. Mean Monthly Flows of the Rio Grande at Albuquerque, 2006-2060



As depicted in Figure 4-1, after flows drop below 260 cfs, DWP diversions will be curtailed and eventually shut down when flow at the Albuquerque gage reaches about 130 cfs. It is difficult to put a valid statistical perspective on the frequency of a flow of 195 cfs at Albuquerque given the upstream reservoir regulation (since the early 1970s) and the additions of SJC water (especially since 1981) during the seasonal low-flow periods. Our evaluation of the record suggests that a mean monthly flow of 195 cfs at Albuquerque (reduced to 130 cfs with the DWP in operation) will probably have a recurrence interval of about once every 7 to 10 years.

Table 5-1 summarizes the number of times that a flow of less than 130 cfs was calculated to occur over the simulated 2006-60 period at Albuquerque, for the No Action and DWP alternatives. Again, there is virtually no difference in the alternatives. In 47 to 46 months out of 660 (about 7 percent of the months), flows are less than 130 cfs at Albuquerque for either No Action or DWP alternatives, respectively.

Hydrologic Effects During Selected Years

We used the array of annual flows at Albuquerque for the 1971-98 period to select normal, low-flow, and extended drought years for closer comparison of the effects of No Action and DWP alternatives on river flow.

Normal Year ¾ 2023

The year 1988 (adjusted as described previously) was inserted into our baseline array as 2023. The mean gaged flow at Albuquerque in 1988 was about 1,210 cfs as compared to 1,410 cfs for the 1971-98 gaged record as a whole.

Figures 5-3(a – e) use the adjusted record for 1988 (2023 in the adjusted array) to compare No Action vs. DWP hydrographs on a monthly basis for San Felipe, Albuquerque, Isleta, San Acacia, and San Marcial. The hydrographs at all stations generally show only small differences between DWP vs. No Action flows:

- San Felipe — DWP flows generally about 65 cfs higher than No Action
- Albuquerque — DWP flows generally 22 cfs lower than No Action
- Isleta, San Acacia, San Marcial — DWP and No Action flows essentially identical

Low-Flow Year ¾ 2040

The year 1977 (adjusted as described previously) was inserted into our baseline array as 2040. The mean gaged flow at Albuquerque in 1977 was about 340 cfs as compared to a mean flow of 1,410 cfs for the 1971-98 period.

Table 5-1. Effects of RG-960 and DWP on Low Flows in Albuquerque Reach

No of Months

Month		Albuquerque (130 cfs) RG-960	DWP
January		0	0
February		0	0
March		0	0
April		2	2
May		7	7
June		7	7
July		5	6
August		5	5
September		10	10
October		10	9
November		1	0
December		0	0
Totals		47	46
		7.1%	7.0%

Percentage for Given Month

Month		Albuquerque (130 cfs) RG-960	DWP
January		0.0%	0.0%
February		0.0%	0.0%
March		0.0%	0.0%
April		4.3%	4.3%
May		14.9%	15.2%
June		14.9%	15.2%
July		10.6%	13.0%
August		10.6%	10.9%
September		21.3%	21.7%
October		21.3%	19.6%
November		2.1%	0.0%
December		0.0%	0.0%
Totals		100.0%	100.0%
Irrigation Season		97.9%	100.0%

Percentage of total

Month		Albuquerque (130 cfs) RG-960	DWP
January		0.0%	0.0%
February		0.0%	0.0%
March		0.0%	0.0%
April		0.3%	0.3%
May		1.1%	1.1%
June		1.1%	1.1%
July		0.8%	0.9%
August		0.8%	0.8%
September		1.5%	1.5%
October		1.5%	1.4%
November		0.2%	0.0%
December		0.0%	0.0%
Totals		7.1%	7.0%
Irrigation Season		7.0%	7.0%

Figure 5-3a - Hydrograph for Rio Grande at San Felipe, 2023
(Adjusted Normal Year, 1988)

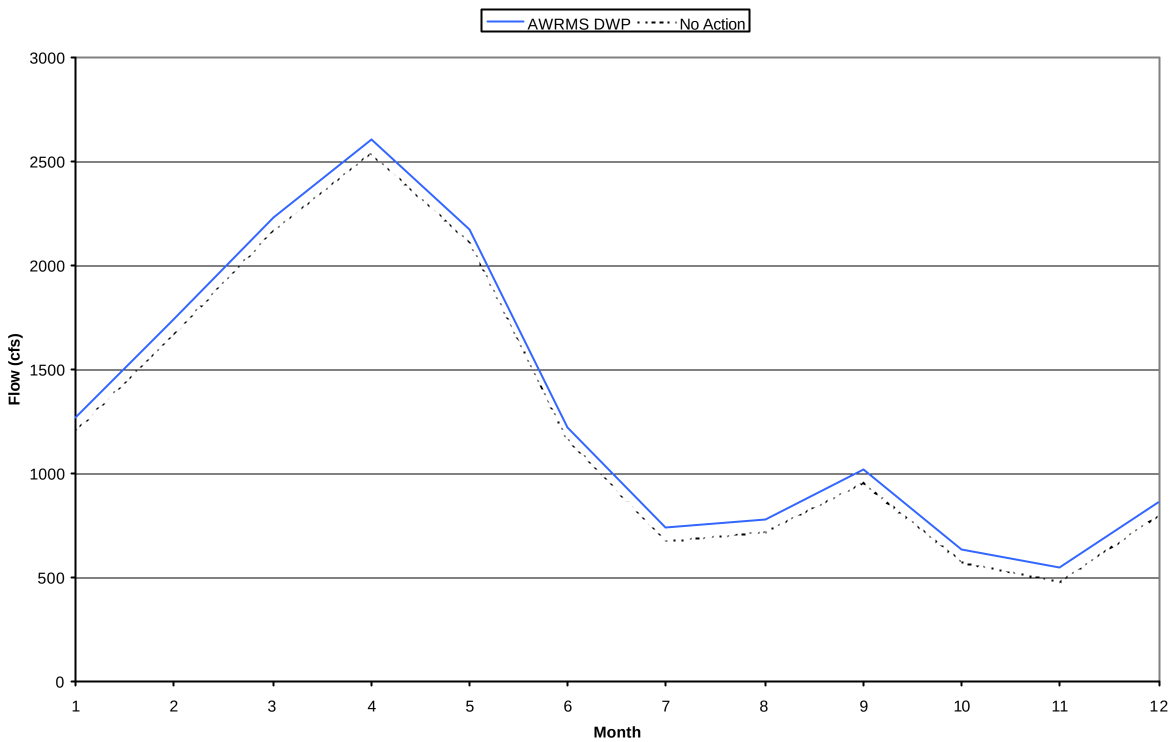


Figure 5-3b - Hydrograph for Rio Grande at Albuquerque, 2023
(Adjusted Normal Year, 1988)

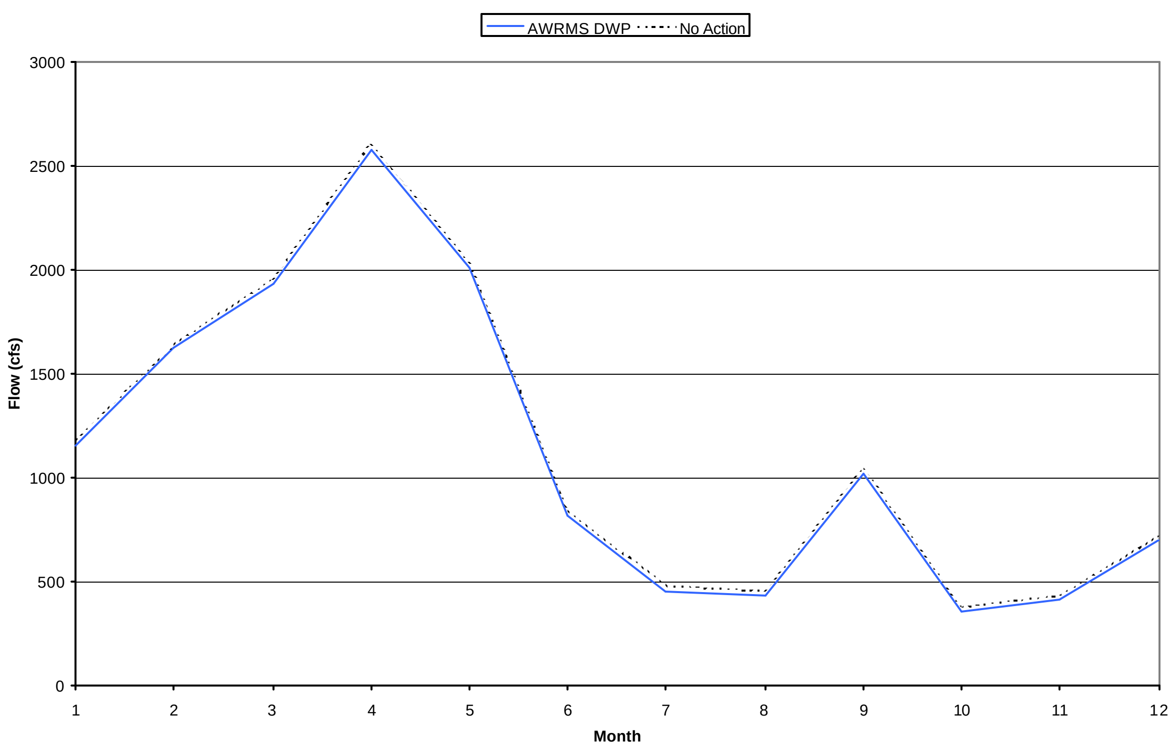


Figure 5-3c - Hydrograph for Rio Grande at Isleta, 2023
(Adjusted Normal Year, 1988)

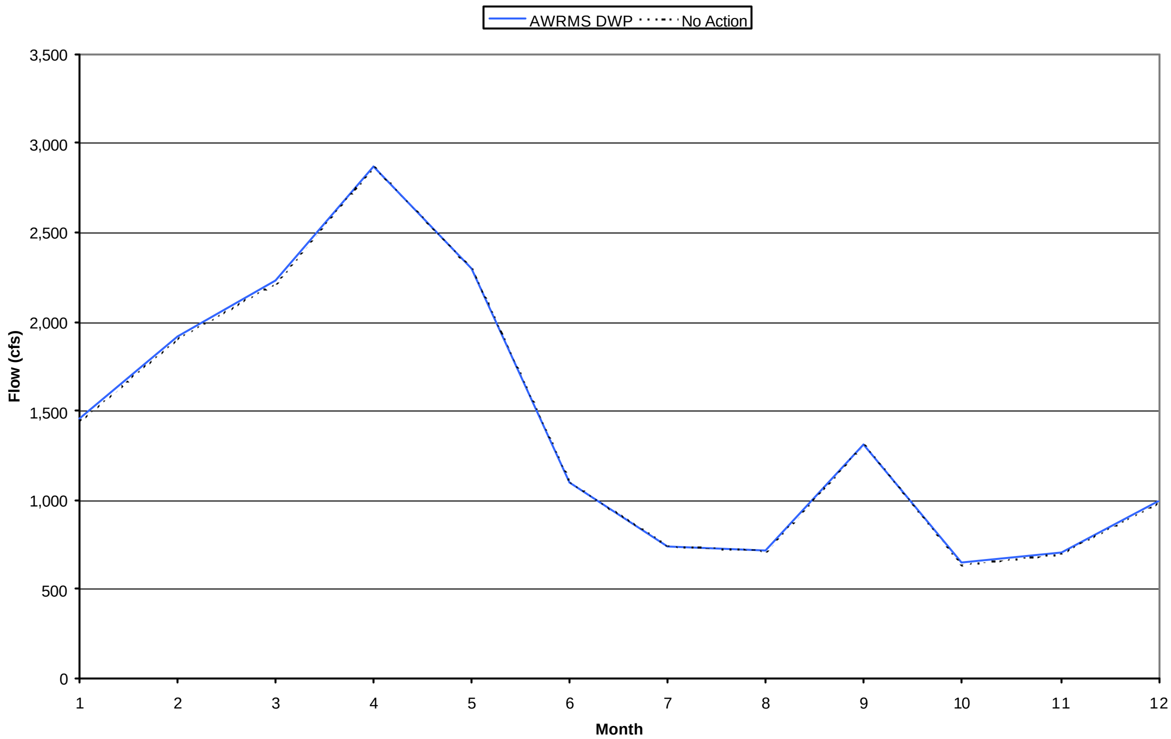


Figure 5-3d - Hydrograph for Rio Grande at San Acacia, 2023
(Adjusted Normal Year, 1988)

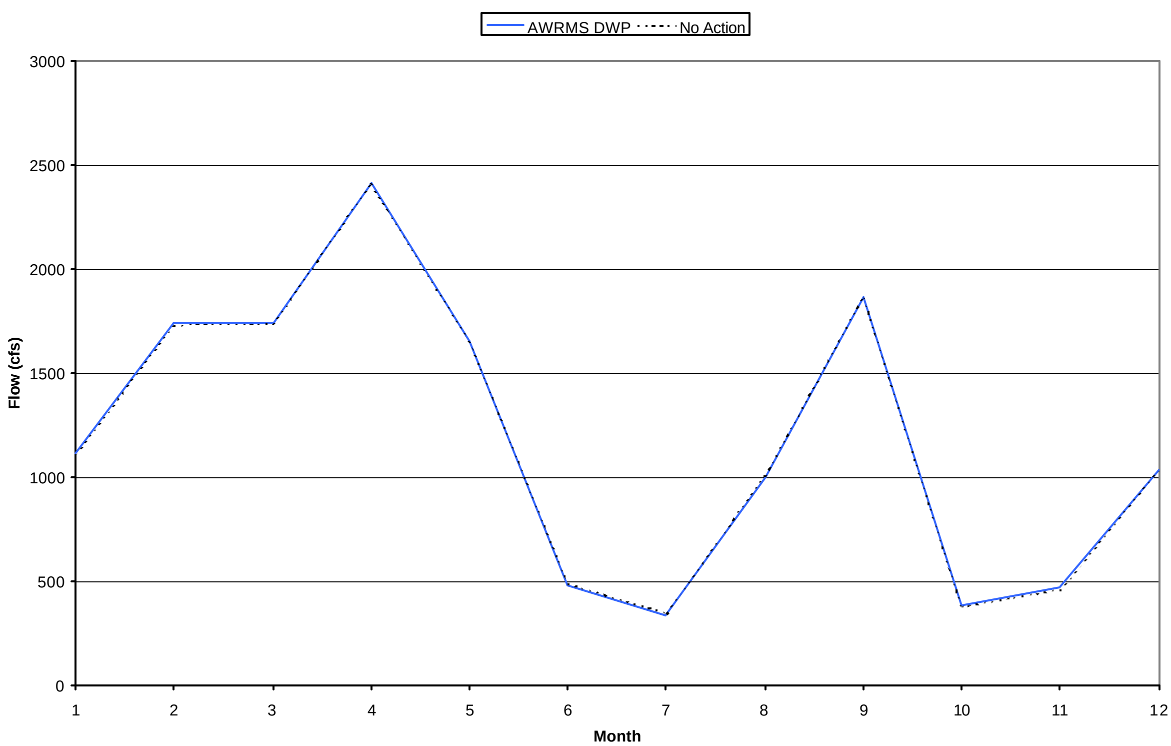
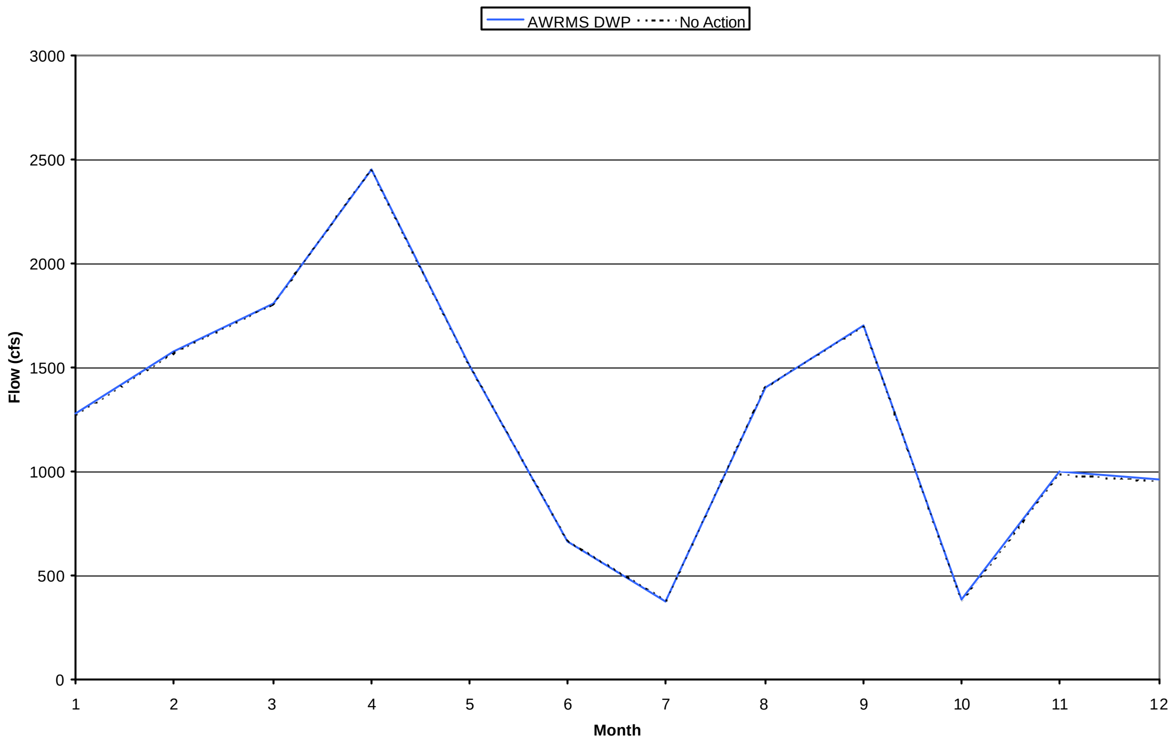


Figure 5-3e - Hydrograph for Rio Grande at San Marcial, 2023
(Adjusted Normal Year, 1988)



Figures 5-4(a – e) use the adjusted record for 1977 (or 2040) to compare No Action vs. DWP on a monthly basis for San Felipe, Albuquerque, Isleta, San Acacia, and San Marcial. The hydrographs at all stations show considerably more differences than for a normal year (2023) between DWP vs. No Action alternatives:

- San Felipe — DWP flows generally 67 cfs higher than No Action, except in the April-May and September-October period when flows are coincident because of DWP curtailment caused by low flows at Albuquerque.
- Albuquerque — DWP flows generally 26 to 29 cfs lower than No Action, except during periods of diversion curtailment in April-May and September-October when DWP flows are 39 cfs higher in April-May and 0 to 31 cfs higher in September-October. Note that flows for No Action are at or near zero in September and October.
- At Isleta, San Acacia, and San Marcial, DWP flows are about 3 to 6 cfs higher in January-March and November-December, 0 to 12 cfs lower in June-August, and 30 to 70 cfs higher during curtailment months of April-May and September-October. Note that at San Acacia and San Marcial, flows are at or near zero in May, June, July, and October for both No Action and DWP scenarios.

Extended Drought ¾ 2024 to 2026

The year 1972 (adjusted as described previously) was placed back-to-back and inserted into the baseline array as 2024-26 to simulate an extended drought. As shown in Table C-3, Appendix C, the mean annual flow in 1972 (478 cfs) is in the range experienced during the severe drought of 1953-56 (296 to 494 cfs). The monthly flows in 1972 at Albuquerque were at or near zero in May, June, July, and August and at or near-zero at San Acacia and San Marcial in April, May, June and July. Thus, 1972 was in many ways more severe than 1977 in terms of zero or near-zero flows.

Figures 5-5(a - e) use the adjusted record for 1972 (repeated thrice in our adjusted array as 2024, 2025, and 2026) to compare No Action vs. DWP on a monthly basis for San Felipe, Albuquerque, Isleta, San Acacia, and San Marcial. The hydrographs at all stations generally show only small difference between DWP vs. No Action flows:

- San Felipe — DWP flows generally 67 cfs higher than No Action, except in the May-August period when DWP releases and diversions are curtailed because of low flow in the Albuquerque reach.
- Albuquerque — DWP flows generally 28 to 35 cfs lower than No Action, except in the May-August curtailment periods of each year when they are 0 to 32 cfs higher.
- Isleta, San Acacia, and San Marcial — DWP flows range from slightly higher (about 3 cfs) to slightly lower than No Action flows (about 10 cfs) except during curtailment months when DWP flows are from 25 to 43 cfs greater than No Action flows. Flows at San Acacia and San Marcial are near zero for May and June for all 3 drought years.

Figure 5-4a - Hydrograph for Rio Grande at San Felipe, 2040 (Adjusted Low Flow Year, 1977)

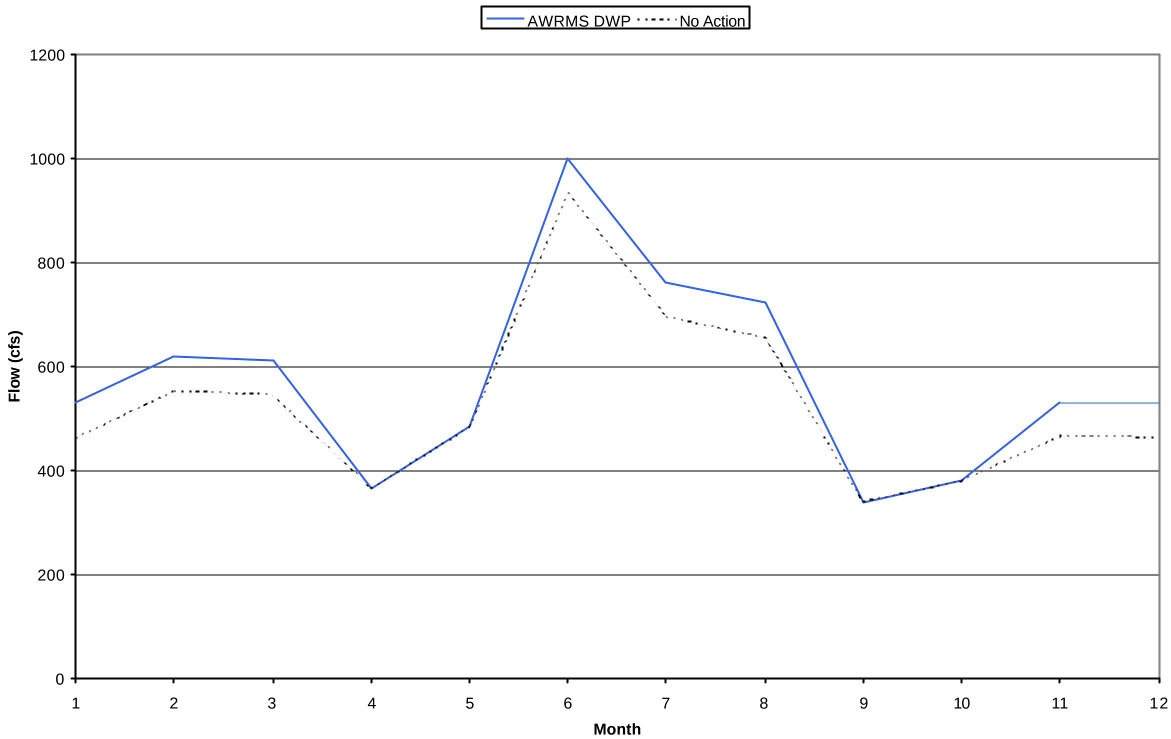


Figure 5-4b - Hydrograph for Rio Grande at Albuquerque, 2040 (Adjusted Low Flow Year, 1977)

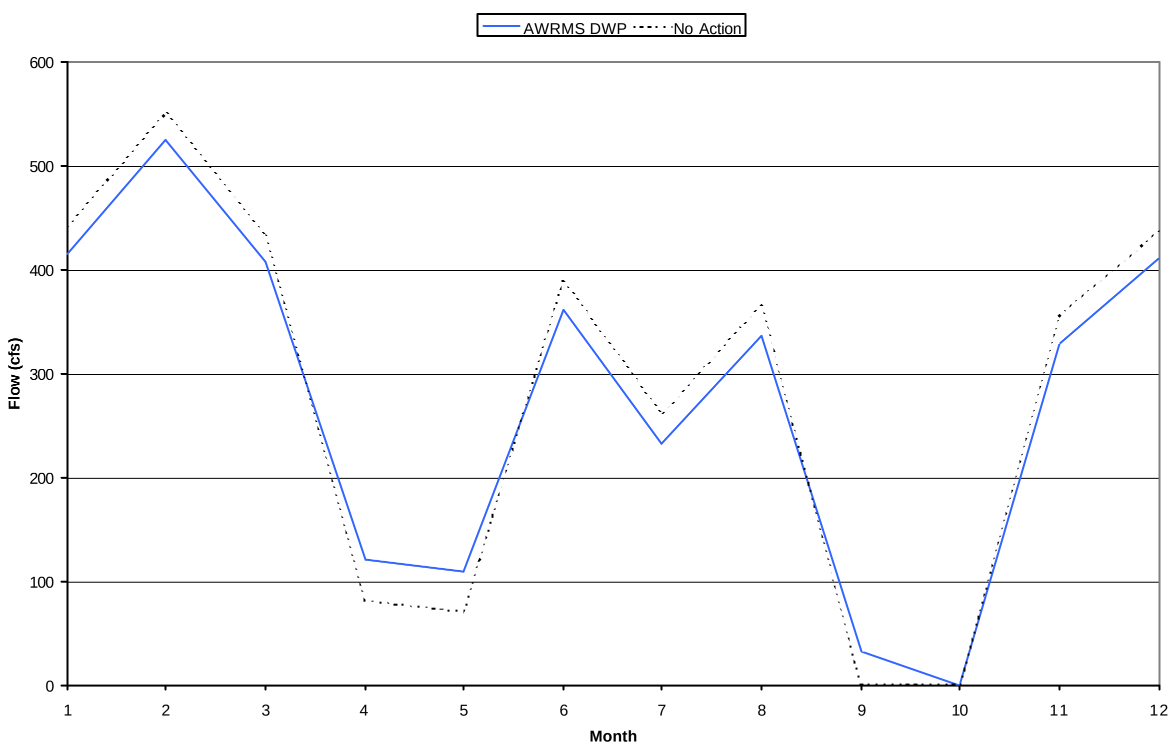


Figure 5-4c - Hydrograph for Rio Grande at Isleta, 2040
(Adjusted Low Flow Year, 1977)

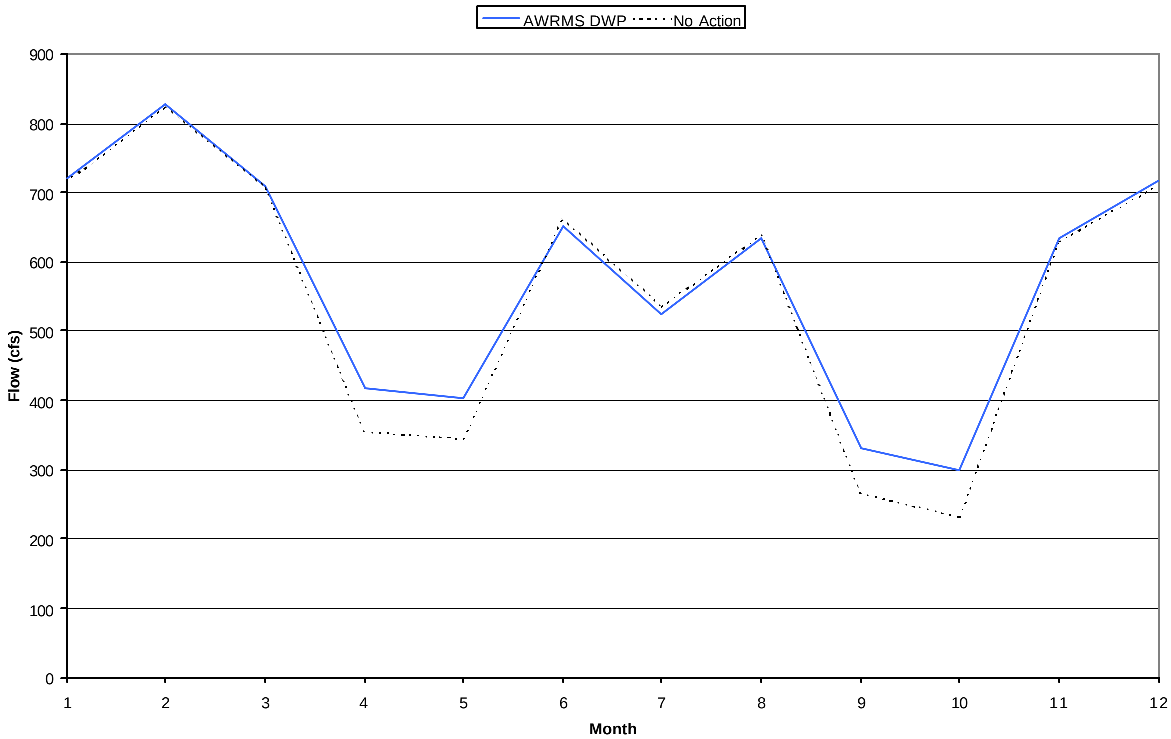


Figure 5-4d - Hydrograph for Rio Grande at San Acacia, 2040
(Adjusted Low Flow Year, 1977)

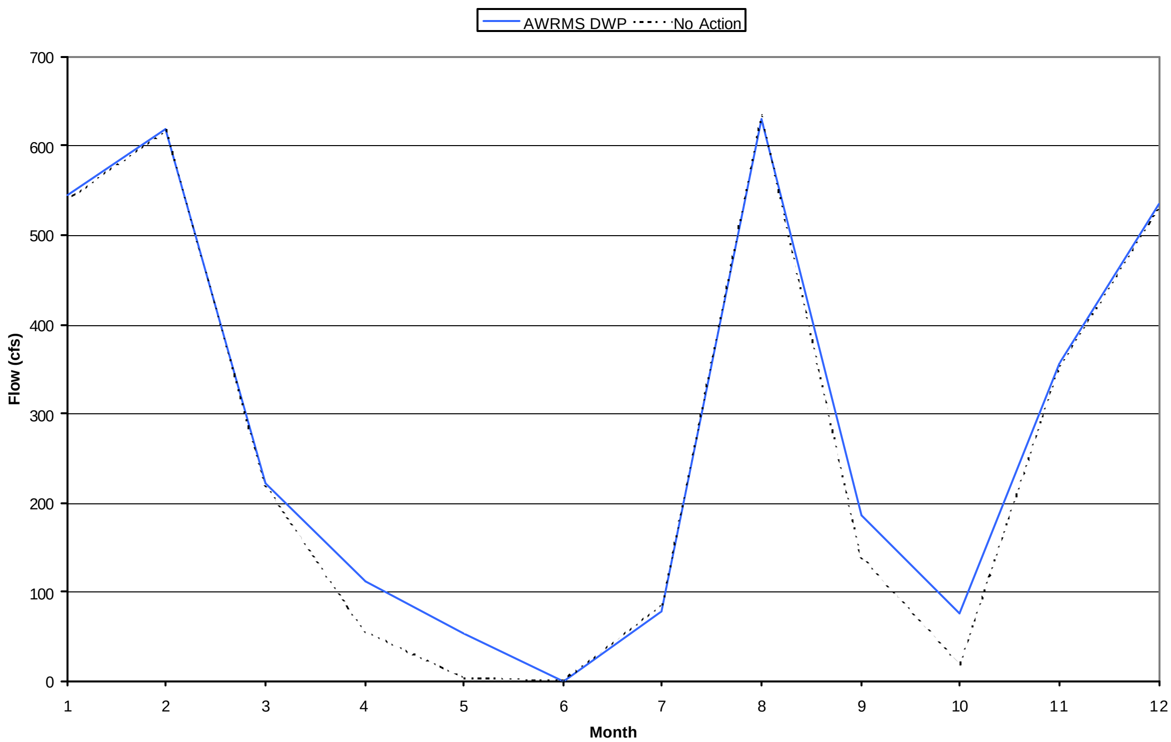


Figure 5-4e - Hydrograph for Rio Grande at San Marcial, 2040
(Adjusted Low Flow Year, 1977)

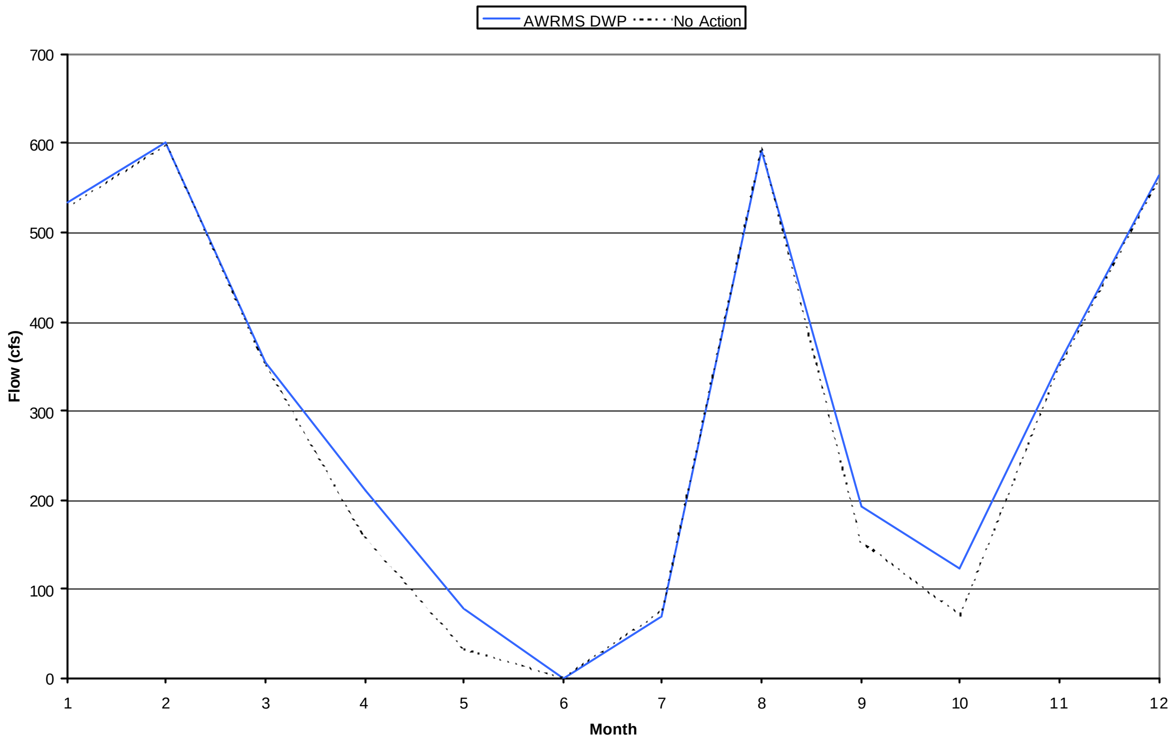


Figure 5-5a - Hydrograph for Rio Grande at San Felipe - 2024,25,26
(Adjusted extended drought, 1972 repeated 3 times)

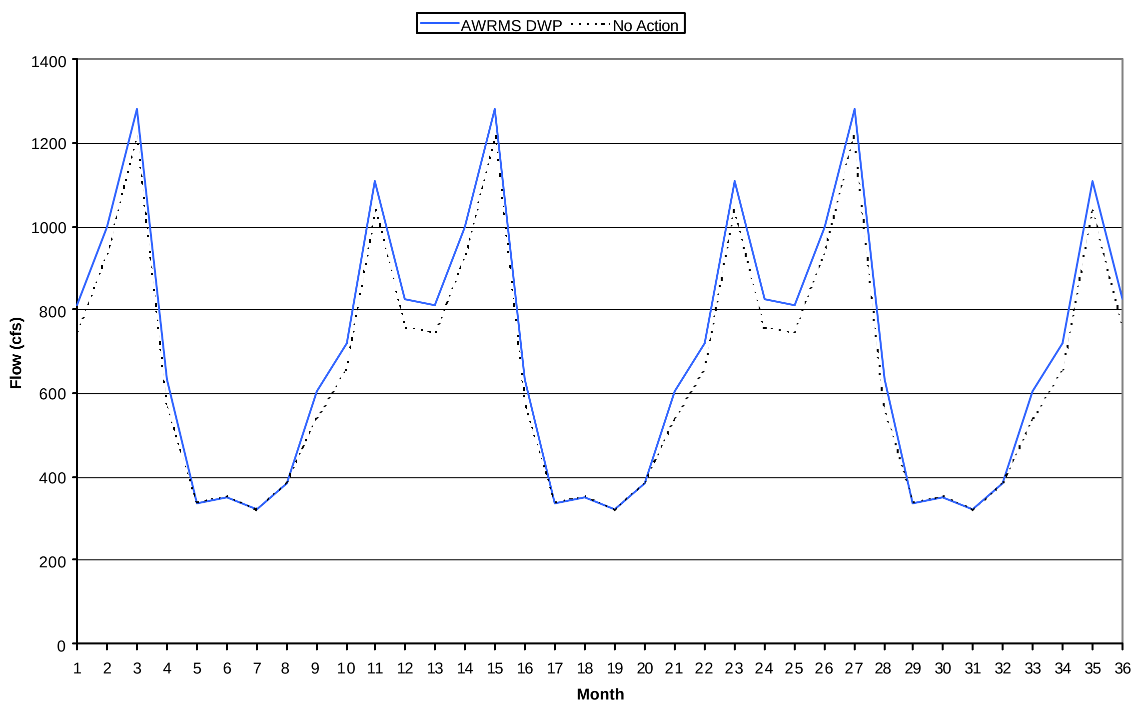


Figure 5-5b - Hydrograph for Rio Grande at Albuquerque - 2024, 25, 26
(Adjusted extended drought, 1972 repeated 3 times)

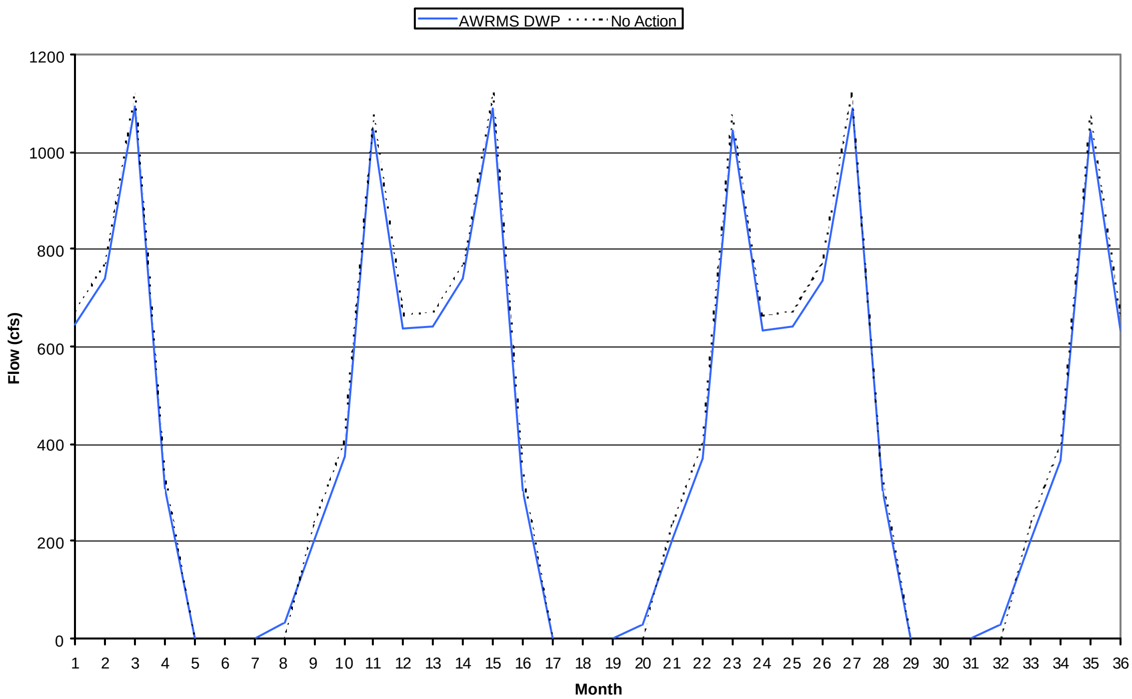


Figure 5-5c - Hydrograph for Rio Grande at Isleta - 2024, 25, 26
(Adjusted extended drought, 1972 repeated 3 times)

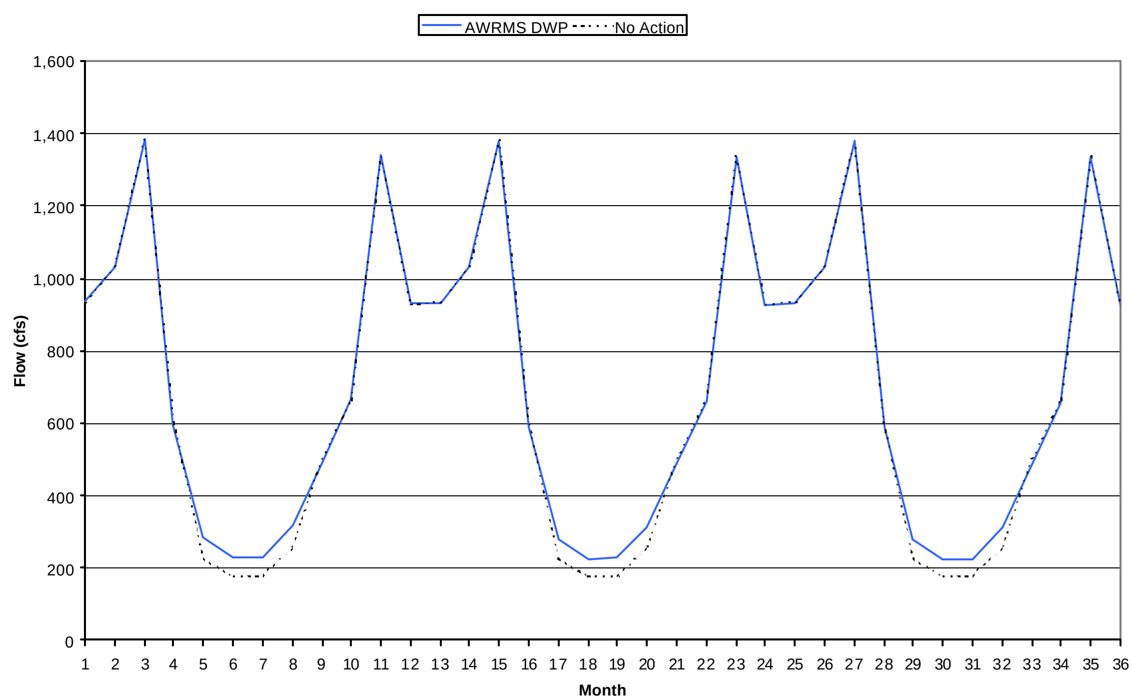


Figure 5-5d - Hydrograph for Rio Grande at San Acacia - 2024, 25, 26
(Adjusted extended drought, 1972 repeated 3 times)

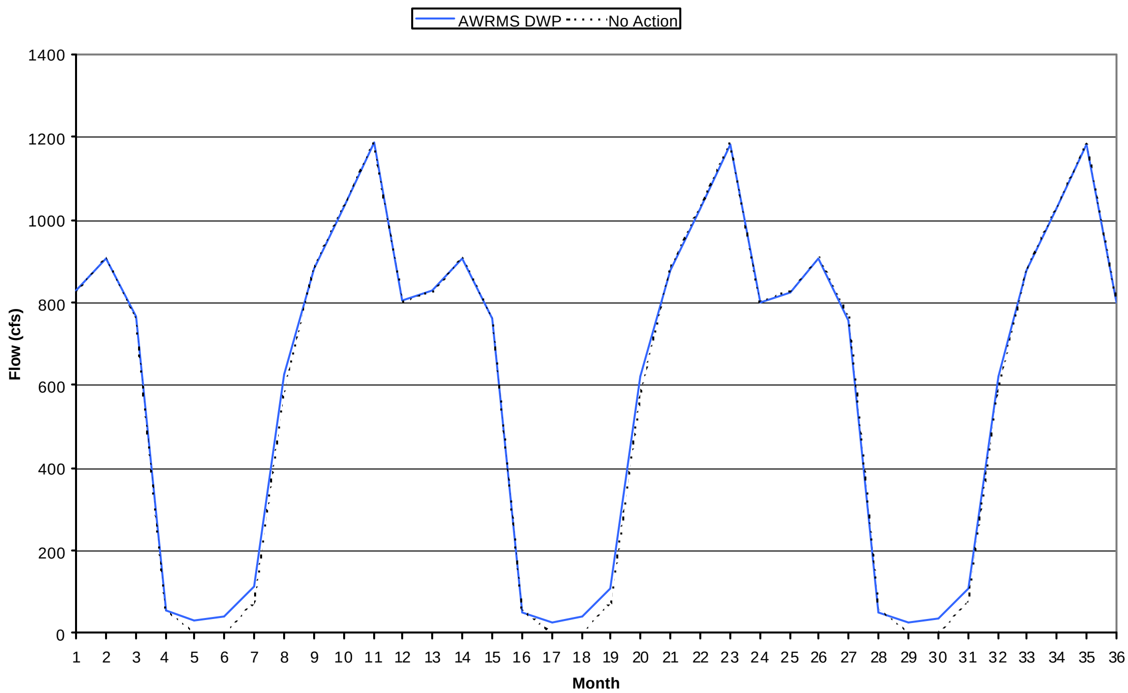
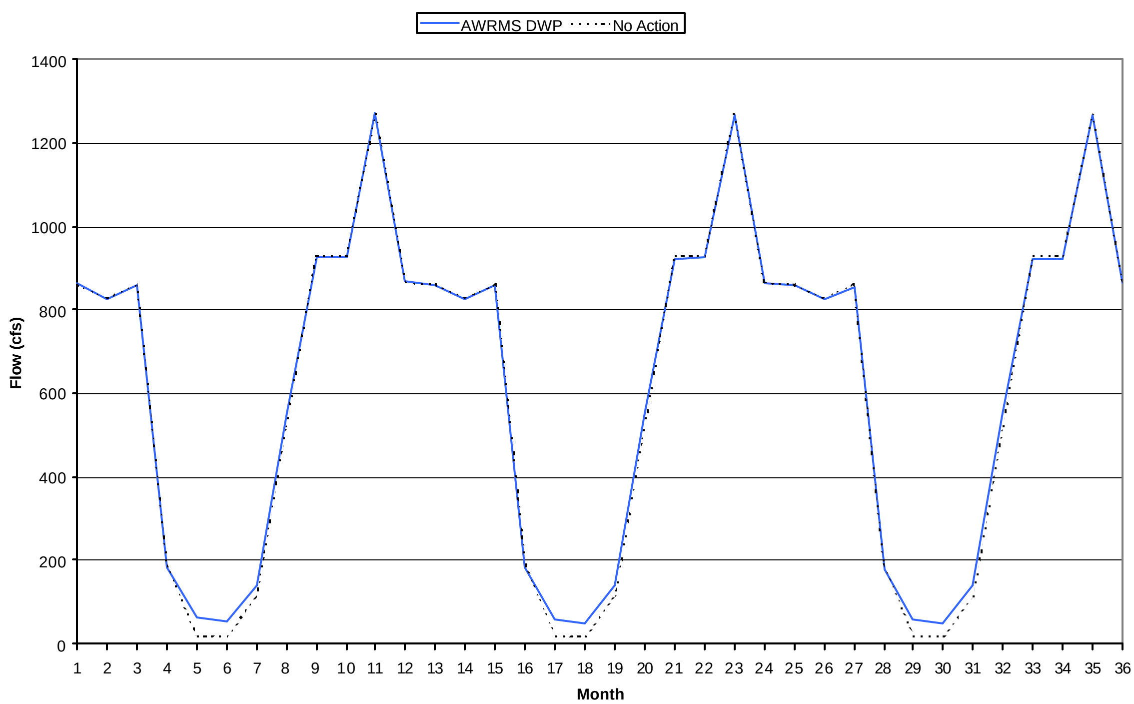


Figure 5-5e - Hydrograph for Rio Grande at San Marcial - 2024, 25, 26
(Adjusted extended drought, 1972 repeated 3 times)



Summary of River Effects

Using the previously described OSE interim ground-water model and the various release-diversion scenarios and adjustments to the 1971-98 hydrologic record, graphs and tables were produced summarizing effects of the No Action and DWP alternatives on the Rio Grande.

Effects in Individual Years, Diversion in Vicinity of Paseo del Norte

Figures 5-6 and 5-7 show the relative effect of the No Action and DWP alternatives in terms of river depletions in the Albuquerque reach between the Bernalillo County line (about 1.5 miles north of Alameda Bridge) and the I-25 Bridge a few miles north of Isleta. Figure 5-6 depicts the effects on river flows in 2030, a near normal runoff year for the Rio Grande. Note the average annual depletion in flows of 130 cfs (65 cfs of native water and 65 cfs of SJC water) occurs at the assumed DWP diversion point above Paseo del Norte Bridge, and that the depletion is almost entirely restored by the return flow from the City SWRP just below Rio Bravo Boulevard. The depletion caused by the No Action alternative is quite similar, with flow a few cubic feet per second lower below Rio Bravo and I-25 Bridge.

Figure 5-7 depicts river flows in 2040, a severe dry year for runoff in the Rio Grande (2040 is built upon the 1977 hydrologic record). As with Figure 5-6, Figure 5-7 shows depletion from a zero baseline to compare the differences in effects due to DWP vs. the No Action alternative. Added to Figure 5-7 is a red line that depicts the depletions that would occur during a month of curtailment in diversion under the DWP alternative. As was the case for the 2030 conditions, the average depletions in flows are similar across the Albuquerque reach for both No Action and DWP scenarios. The No Action alternative results in a lower flow (5 to 20 cfs lower) in the river below Rio Bravo. Note that there is a marked improvement (about 66 cfs more than No Action) in flows during a curtailment month under the DWP alternative (see red line). This improvement points to a clear advantage of the DWP alternative in low-flow months. That is, because of the ability to stop diversions under the DWP alternative, flow depletions in the Albuquerque reach would be considerably less than under the No Action alternative. Also, flows at downstream gaging stations on the river would be higher during curtailment periods under DWP than for the No Action alternative.

Effects in Individual Years, Diversion at the Existing Angostura Dam

Figures 5-8 and 5-9 show the relative effect of the No Action and DWP alternatives in terms of river depletions in the Albuquerque reach between the Angostura Dam and the I-25 Bridge a few miles north of Isleta with an assumed DWP diversion at Angostura. As with Figure 5-6, Figure 5-8 depicts the effects on river flows in 2030. Again, the average annual depletion in flows of 130 cfs (65 cfs of native water and 65 cfs of SJC water) occurs at Angostura, and that depletion is almost entirely restored by the return flow from the SWRP just below Rio Bravo. The depletion caused by the No Action alternative is less in the reach between Angostura and the Bernalillo County line, but more pronounced than the DWP depletion from the County line to Rio Bravo. After the SWRP return, No Action flows are quite similar to DWP flows at Isleta (I-25) and below. Figure 5-9, depicting 2040 flows with

Figure 5-6. Simulated Average Flow Depletions, 2030, in Albuquerque Reach of Rio Grande Under DWP and RG 960 Alternatives

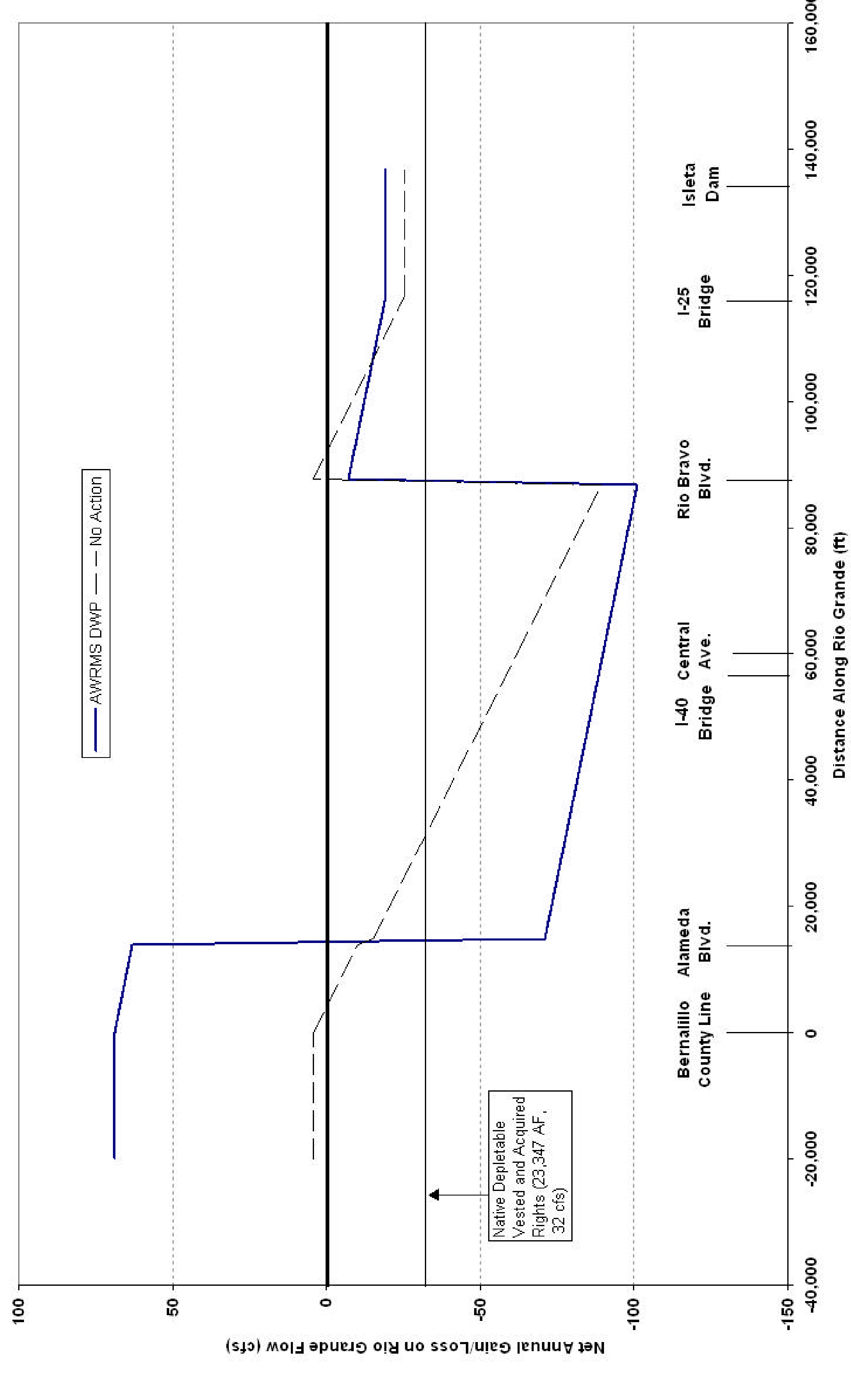


Figure 5-7. Flow Depletions in the Albuquerque Reach of Rio Grande During a Simulated Low-Flow Year and a Curtailment of DWP Diversion, 2040 Under DWP and No Action Alternatives

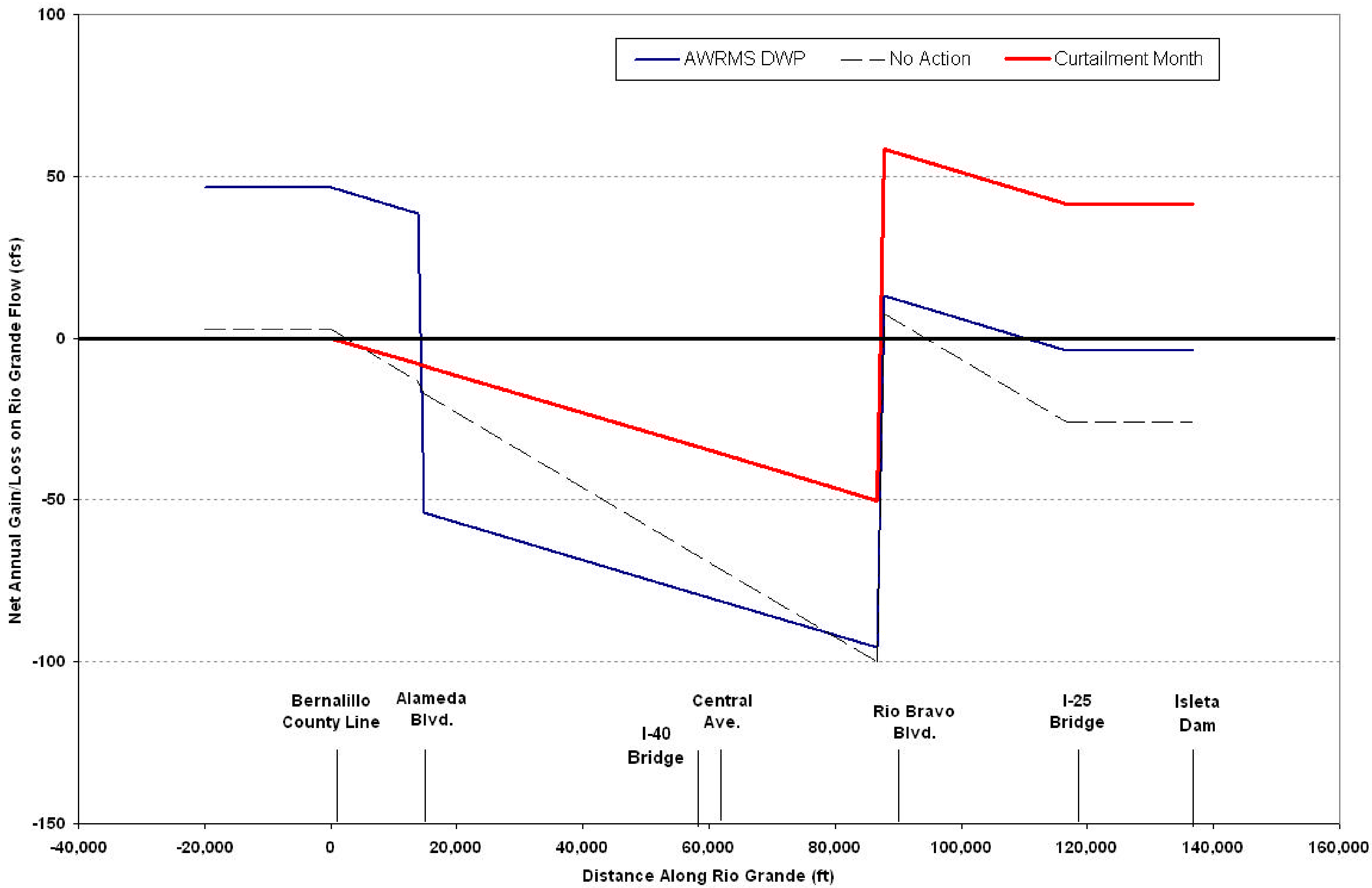


Figure 5-8. Simulated Average Flow Depletions, 2030, in Albuquerque Reach of Rio Grande Under DWP and No Action Alternatives (Diversion at Angostura)

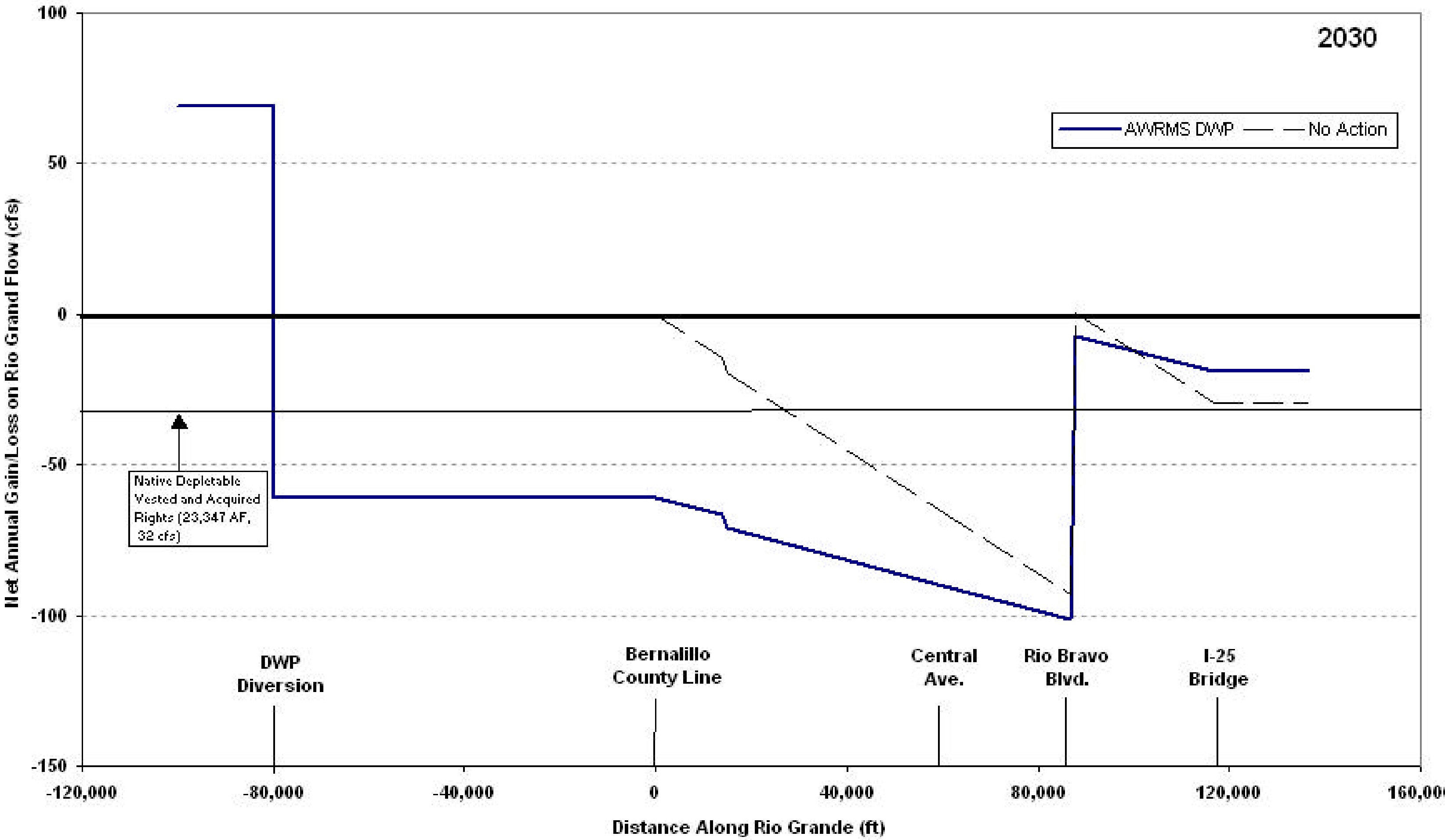
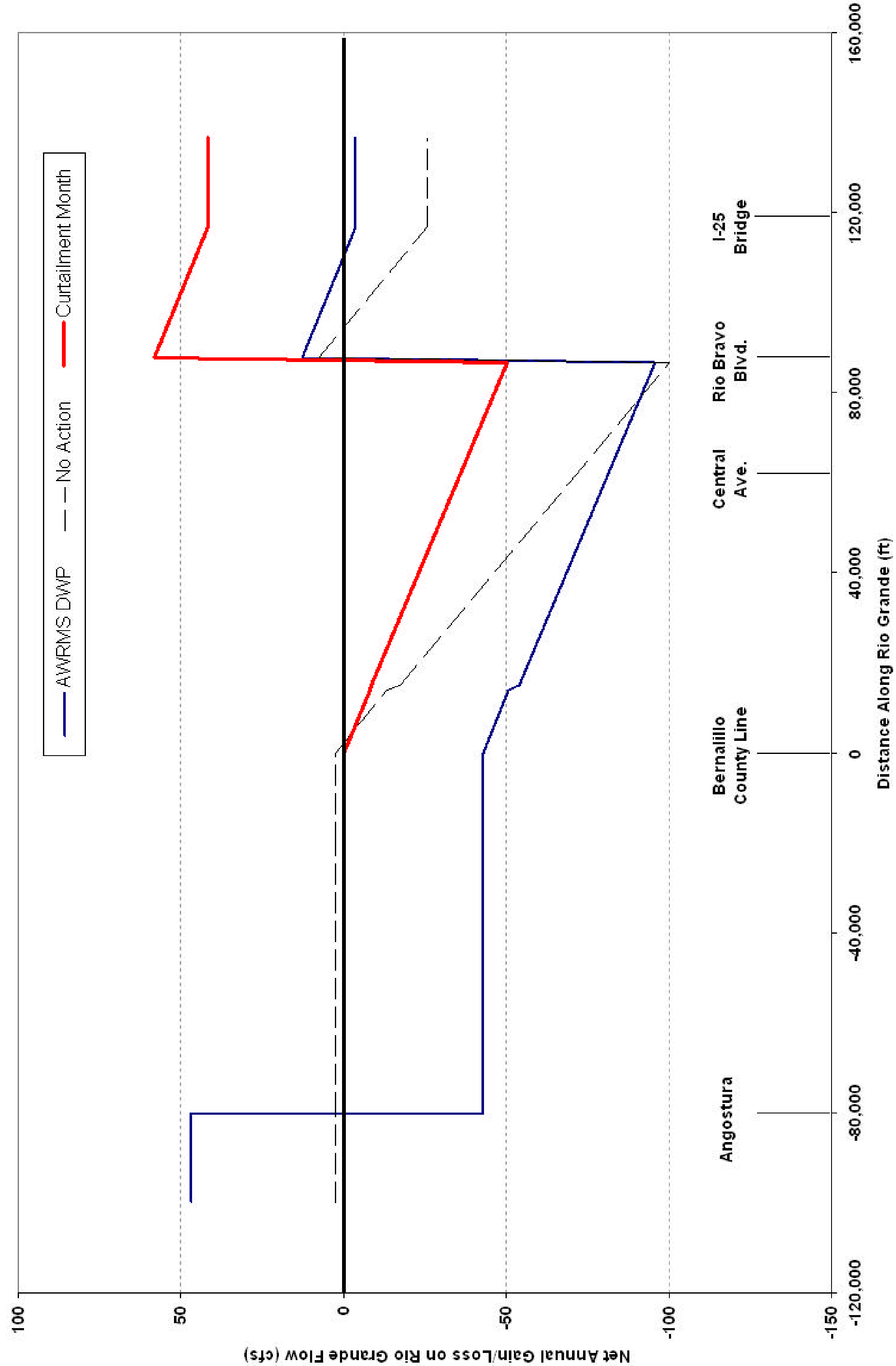


Figure 5-9. Flow Depletions in the Albuquerque Reach of Rio Grande During a Simulated Curtailment of DWP Diversion, 2040, Under DWP and No Action Alternatives(Diversion at Angostura)



a curtailment month in red line, follows a pattern that combines those previously described for Figures 5-7 and 5-8.

Summary of Depletions, 2006-60

The depletions across the Albuquerque reach caused by either the No Action or DWP alternatives are not static and change with time. Tables 5-2 and 5-3 summarize conditions in 2006, 2012, 2020, 2030, 2040, and 2060 at four locations from the Bernalillo County line to the I-25 Bridge under an assumed DWP diversion at Paseo del Norte and Angostura, respectively.

TABLE 5-2

Comparison of Effects of DWP and No Action Alternatives on Rio Grande Flows in the Albuquerque Reach, 2006-2060 for Diversion at Paseo del Norte

Year	Location							
	Bernalillo County Line		Central		Rio Bravo		I-25 Bridge (Isleta)	
	No Action	DWP	No Action	DWP	No Action	DWP	No Action	DWP
	Incremental Differences in Flow in cfs							
2006	3	88	-54	-70	-78	-91	-23	-33
2012	3	52	-55	-75	-80	-91	-30	-33
2020	4	69	-57	-87	-82	-96	-28	-24
2030	4	69	-62	-90	-89	-101	-25	-19
2040	3	47	-70	-80	-100	-96	-26	-4
2050	4	69	-74	-99	-106	-114	-26	-15
2060	4	69	-84	-108	-121	-126	-32	-14

TABLE 5-3

Comparison of Effects of DWP and No Action Alternatives on Rio Grande Flows in the Albuquerque Reach, 2006-2060 for Diversion at Angostura

Year	Location							
	Bernalillo County Line		Central		Rio Bravo		I-25 Bridge (Isleta)	
	No Action	DWP	No Action	DWP	No Action	DWP	No Action	DWP
	Incremental Differences in Flow in cfs							
2006	3	-19	-54	-70	-78	-91	-23	-33
2012	3	-35	-55	-75	-80	-91	-30	-33
2020	4	-61	-57	-87	-82	-96	-28	-24
2030	4	-61	-62	-90	-89	-101	-25	-19
2040	3	-43	-70	-80	-100	-96	-26	-4
2050	4	-61	-74	-99	-106	-114	-26	-15
2060	4	-64	-84	-108	-121	-126	-32	-14

The incremental annual and monthly differences in Rio Grande flows shown in Figures 5-6 through 5-9, and summarized in Tables 5-2 and 5-3, are based on comparison of DWP and No Action flows to a baseline that would have occurred without any City effects (i.e., no well pumpage, no surface diversions, no wastewater return flows, etc.). Thus, for example, at the Bernalillo County line the assumption is that relative to the baseline, No Action flows are a few cfs (3 to 4 cfs) higher to account for SJC releases for the Nonpotable Surface Water Project (about 3,000 ac ft/yr through 2060). In contrast, DWP flows at the Bernalillo County line are much greater owing to the release of SJC water for the DWP. For example, in 2006 SJC releases for the DWP are 85 cfs more than for No Action at the County line because of the extra SJC water released in early project years to offset the lingering effects of historical pumpage. DWP flows at the County line are normally 65 cfs more in most other years except when less SJC water is released in years of curtailed diversion (e.g., 2012 and 2040).

Because of the 'borrowing' of 65 cfs of native water along with 65 cfs of SJC water at the DWP diversion point, No Action flows are always higher (about 10 to 30 cfs more) than DWP flows at Central Avenue. At Rio Bravo, just above the SWRP return flow, No Action flows are generally slightly higher on average than DWP flows until several decades into the project. At the I-25 Bridge (Isleta), No Action and DWP flows are very similar until after 2020 when the effects of continued ground-water pumpage cause more depletions under No Action than under the DWP scenario.

Overall Water Balance and Net Effects

The OSE interim ground-water model of the Albuquerque basin was used to simulate the overall effects of the No Action and DWP alternatives on the Rio Grande on an annual basis throughout the 2006-60 project period. Spreadsheets summarizing the ground-water model runs and resulting water balances are provided in Appendix E. Population and water demand assumptions were based on the 'continued trends with conservation' scenario described in CH2M HILL (1995, Appendix A).

Figure 5-10 shows the steady increase in City pumping from ground-water wells over time with the No Action scenario (i.e., pumping increases with increases in population to meet overall demand). Likewise, the net effect on the river increases over time as aquifer drawdowns cause more river seepage.

Under No Action, the net effect on the Rio Grande increases from about 12,380 ac-ft/yr in 2006 to 21,280 ac-ft/yr in 2060 (see Table E-1). The OSE's present limit on allowable pumpage is 155,000 ac-ft/yr, a level that would be exceeded by about 2052 under the No Action scenario.

Figure 5-10 - Effect of RG-960 Alternative (continued pumping) on Rio Grande

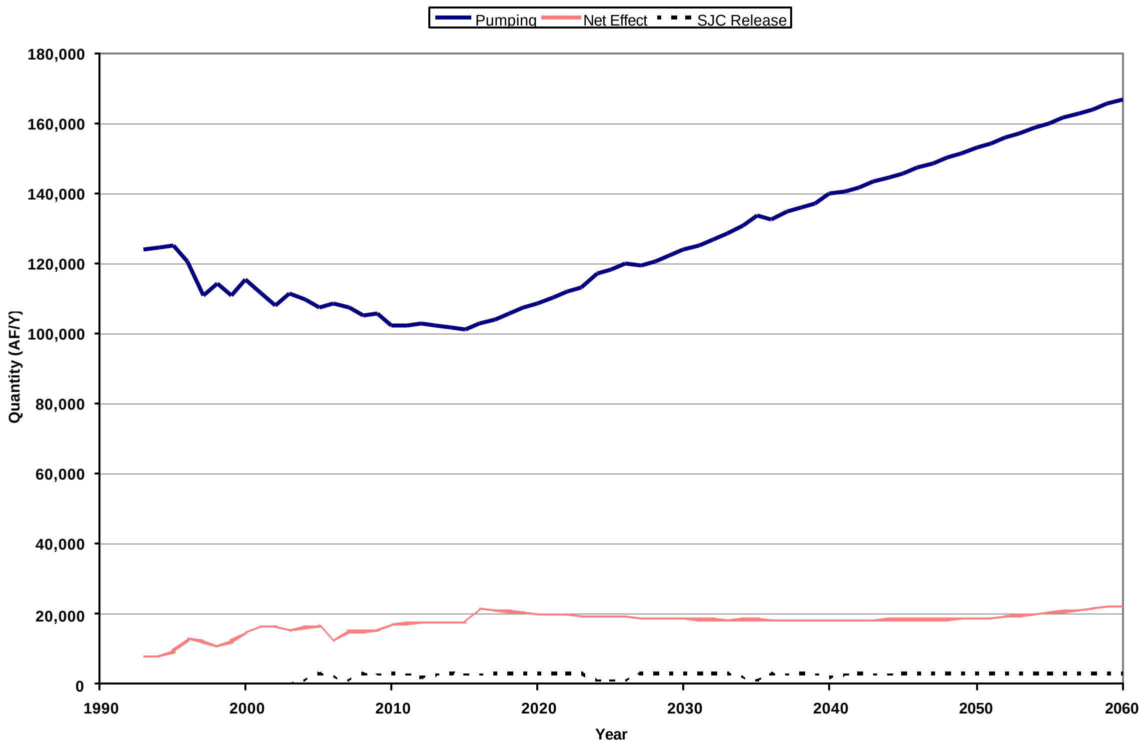
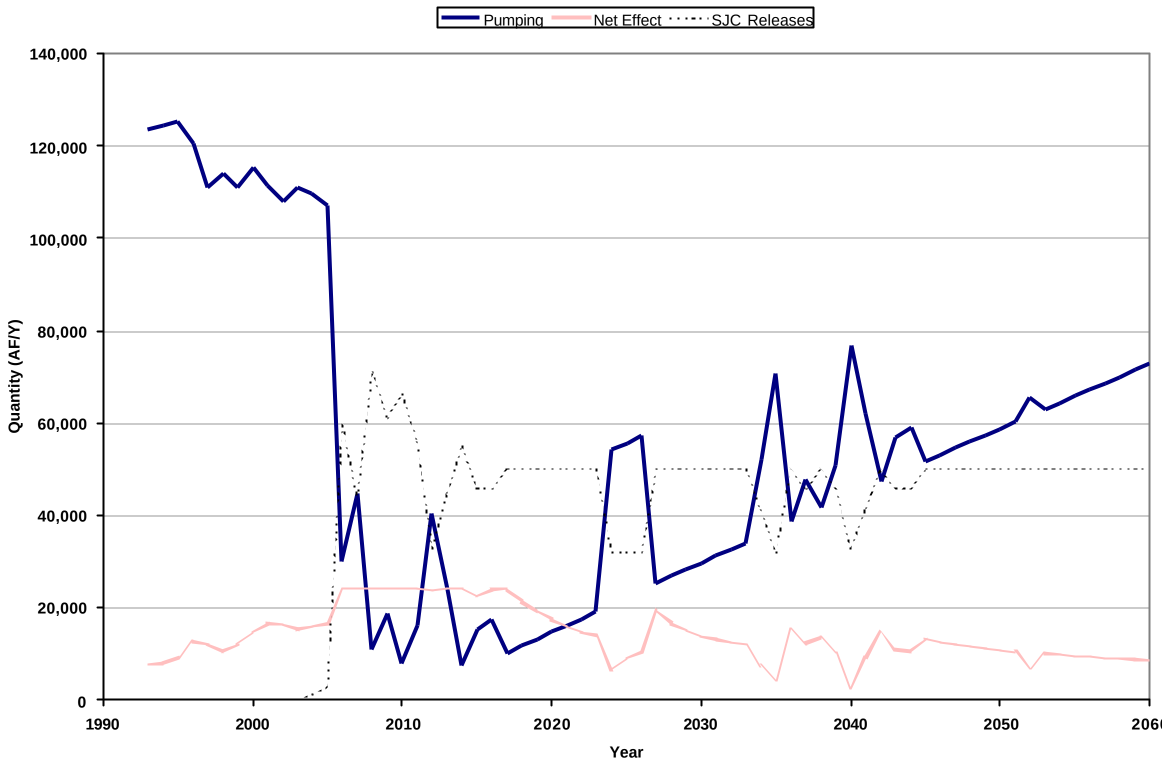


Figure 5-11 shows the City pumping from ground-water wells (much less than No Action), SJC releases, and the net effect on the river over time with the DWP operating according to the previously stated (Figures 4-1 and 4-2) operational criteria. (Note that as described previously [see discussion for Figures 4-3(a)], extra releases are made in early DWP years to counter the lingering effects of historical pumping on river seepage and the reduced quantities of ground water returned to the river at the SWRP outfall.) When flow in the Rio Grande drops below 260 cfs, project diversions are curtailed, and wells are pumped more heavily. This causes the upward 'spikes' in pumping shown in Figure 5-11. Net effects on the Rio Grande also are changed by these curtailments. During years of curtailed diversions, additional ground water is returned to the river through the SWRP outfall below Rio Bravo. Because increased seepage of the Rio Grande due to additional pumping will generally not occur in the year of increase (but later), the river will be 'surcharged' with water (and net effects will go down) in years of curtailment (i.e., during low-flow years or extended drought periods).

Figure 5-11 indicates that under DWP, the net effect on the Rio Grande is 23,347 ac-ft/yr from 2006 through 2011 and varies between about 23,000 ac-ft/yr and 4,000 ac-ft/yr between 2011 and 2060. Note that ground-water pumpage under the DWP never reaches the present OSE allowable level of 155,000 ac-ft/yr and that the City's current vested and acquired rights are always sufficient to offset the net effects on the river. It should be realized, however, that ground-water pumping under the DWP could exceed the

Figure 5-11 - Effect of DWP Operation on Rio Grande



limit of 155,000 ac-ft under RG-960 in any year after about 2052 if the DWP surface diversion were shut down for an entire year rather than the few months assumed in the present analysis.

Effects on 'Hydraulic Geometry' of the Albuquerque Reach

As described previously, the DWP release / diversion scheme will cause a reach of the river between the diversion point and the SWRP to be 'depleted' relative to historical flow (1971-98 gaged flows). On the other hand, the DWP will cause the reach from Cochiti to the diversion point to be 'surcharged' relative to historical flow. In either case, the maximum change will (in most years) be ±65 cfs relative to 'historical gaged' flows. Relative to No Action flows, DWP flows will (in most years) be a maximum of about 65 cfs higher above the diversion point and a maximum of 30 to 47 cfs less in the reach between the DWP diversion and the SWRP outfall below Rio Bravo. The question arises as to how such changes will effect the water depths and velocities of flow between Angostura and Isleta (termed the Albuquerque reach).

A study was undertaken (CH2M HILL, 2000c) to estimate changes in wetted channel characteristics ('hydraulic geometry') of the Albuquerque reach that may be caused by implementation of the DWP. As evidenced by previous discussion and comparison of simulated hydrographs, there will be little difference in DWP and No Action flows at gaging stations in the MRG basin. Although the No Action alternative (like the DWP) will cause a depleted section of the Albuquerque reach relative to historical flows; such depletion will be spread throughout the reach and will increase with distance below Paseo del Norte until the return flow point for SWRP effluent below Rio Bravo (see Figures 5-6 through 5-9). In contrast, the DWP depletions will occur immediately below Paseo del Norte and then increase slightly downstream until the SWRP outfall.

To be conservative in our analysis of the effects of DWP diversions on the 'hydraulic geometry' of the Albuquerque reach, we chose to compare DWP effects to historical gaged (1971-98) conditions. Such effects are of interest (primarily) for assessing possible environmental impacts (covered in the City's Draft EIS for the DWP) on the Rio Grande silvery minnow.

The river channel in much of the Albuquerque reach is comprised of a mobile, sandy bed that is generally confined within a 500- to 600-foot-wide (±) engineered floodway. Inspection of USBR aerial photographs of the river taken during a sustained, low-flow period in February 1992 shows that the channel is somewhat narrower and more 'single channeled' from Angostura to Bernalillo and wider and more braided from Bernalillo to the Isleta diversion dam.

Based on the 1971-98 flow record of the USGS gage at the Central Avenue Bridge, mean annual flow at Albuquerque has been 1,410 cfs, whereas mean low monthly flows (typically October) were about 490 cfs. An analysis of flow, cross section, and discharge measurements made by USGS and USBR was used to establish flow conditions and typical channel characteristics of the 40-mile Albuquerque reach. The method of Leopold, et al. (1964) was used to calculate 'hydraulic geometry' characteristics that were, in turn, coupled with the selected flow conditions to estimate changes in water depths likely to be caused by proposed DWP releases and diversions.

We concluded that the ***d*** (depth) vs. ***Q*** (flow or discharge) relations for the entire 40-mile Albuquerque reach vary within a range of $d = 0.1\,Q$ and $d = 0.1\,Q^{0.47}$. These equations were applied to 1971-98 gaged flows at Albuquerque with appropriate ±65 cfs changes made to simulate DWP operations. Results are summarized in Table 5-4 on the following page.

Using the ***Q*** *vs.* ***d*** equations and flows summarized above suggests that maximum changes in water depths in the Albuquerque reach caused by DWP will be quite minor — on the order of ±0.1 foot during a mean low monthly flow condition. During severe low flow (170 cfs equivalent at Albuquerque gage), water levels could be reduced by up to 0.3 foot (relative to historical, less relative to No Action) in narrowest sections of the river under a constant DWP diversion of 130 cfs.

Inspection of historical discharge measurements made in the river in the vicinity of the Albuquerque gage at Central Avenue (a narrow section) suggests that the reduction in flows of up to 65 cfs from 135 to 70 cfs immediately below the DWP diversion, or from 170 to 105 cfs at the Albuquerque gage (see Figure 4-1), will have the following effects:

- Velocity — 0.1 to 0.2 foot per second (ft/s) reduction within a typical range of 1.0 to 1.4 ft/s
- Width — 20 to 30 ft reduction within a typical range of 70 to 130 ft, respectively

TABLE 5-4
Estimated Water Depths in Albuquerque Reach of Rio Grande With and Without Constant DWP Diversion of 130 cfs

Streamflow Condition	Wide Section $d = 0.1\,Q^{0.30}$		Narrow Section $d = 0.1\,Q^{0.47}$	
	With DWP	Historical Gaged	With DWP	Historical Gaged
Between Angostura and Diversion Point (max of 65 cfs more in river)				
Severe Monthly Low (135 vs. 70 cfs)	0.4’	0.4’	1.0’	0.7’
Mean Monthly Low (555 vs. 490 cfs)	0.7’	0.6’	1.9’	1.8’
Mean Annual (1,475 vs. 1,410 cfs)	0.9’	0.9’	3.1’	3.0’
Below DWP Diversion (max of 65 cfs less in river except during curtailment)				
Severe Monthly Low (70 vs. 70 cfs)[a]	0.4’	0.4’	0.7’	0.7’
Mean Monthly Low (425 vs. 490 cfs)	0.6’	0.6’	1.7’	1.8’
Mean Annual (1,425 vs. 1,490 cfs)	0.9’	0.9’	3.0’	3.1’

[a] During periods of non-curtailment, flows could be 135 vs. 70 cfs below DWP diversion. In this case, depths in narrow section could be reduced from 1.0’ (at 135 cfs) to 0.7’ (at 70 cfs) – i.e., a 0.3’ difference.

Effects on Sediment Transport

For the AWRMS-DWP project, the sedimentation questions relate to how the operation of a surface diversion at the existing dam at Angostura, or of a new diversion near Paseo del Norte, might affect sediment transport in the Rio Grande. While additional specific and design-related hydraulic and sediment transport evaluations are required to fully answer such questions, several preliminary conclusions have been made.

- The relatively minor amounts of additional SJC water in the Rio Grande caused by operation of the AWRMS project will, in and of itself, have no measurable effect on sediment transport characteristics.
- Operation of renovated Angostura Dam to divert 130 cfs for the AWRMS project should have virtually no effect on the river sediment transport regime.
- The subsurface diversion alternative would have no effect on the river sediment transport regime.
- Operation of a new 3-foot-high adjustable diversion facility at Paseo del Norte will effect sediment transport, but locally rather than reach-wide. Larger-sized particles in the medium sand-sized range and some of the finer-sized suspended and bed material, will tend to settle out in the 1,000- to 2,000-foot-long pool behind the dam. However, because the dam will be lowered to river bottom elevation during high flows, much of

this deposited material will be resuspended and moved downstream – thus returning the river bed to its equilibrium level. Moreover, localized accumulations on either side of the diversion dam in the immediate upstream pool can be flushed by lowering individual sections of the adjustable dam face.

- Below the diversion structure at the exit of the sluiceway and fishway, there may be accumulations of material, or in some areas, scour holes. Areas of engineered bank protection through the diversion section will be needed to control possible bank cutting during high-flow events. Such concerns and conditions will be localized and manageable with monitoring and periodic maintenance activities and will not alter the overall sediment transport regime in the Albuquerque reach of the Rio Grande.

Section 6

Effects of DWP and No Action Alternatives on the Albuquerque Basin Aquifer and Riverfront Ground Water

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Effects of DWP and No Action Alternatives on the Albuquerque Basin Aquifer and Riverfront Ground Water

To evaluate and compare the effects of the DWP and No Action alternatives on the Albuquerque basin aquifer, runs were made on the OSE interim ground-water model to examine two issues for the 2006-60 period:

1. The water level drawdowns in the main basin aquifer caused by each alternative
2. The amounts of water derived from aquifer storage

A second, more detailed and localized model based on the MicroFem© code was developed to evaluate riverfront (bosque) water level declines caused by the subsurface alternative.

Drawdowns in the Basin Aquifer

The OSE interim ground-water model of the Albuquerque basin aquifer was run under the No Action and DWP scenarios to compare the effects on water level drawdowns. Projected pumping by the City (and others) through 1994 was the same for both models and is summarized in USGS (1995). Pumpage from 1995 through 2001 was based on City records, and after 2001 on projections derived from estimated per capita demands and population estimates (CH2M HILL, 2002b). Beginning in 2006, the No Action and DWP scenarios diverge in terms of the quantities of pumping (see previous discussion in ***Summary of River Effects***).

Figure 6-1 shows the simulated drawdowns from pre-development conditions through 2040 in the Albuquerque basin aquifer under the No Action alternative. Projected drawdowns approach or slightly exceed the OSE-prescribed subsidence threshold of 250 feet in small areas of west Albuquerque and approach 200 feet in small areas of northeast and southeast Albuquerque. Drawdowns in 2040 under the DWP (Figure 6-2) are generally less than 150 feet in the same areas and less than 100 feet elsewhere.

By 2060 under No Action pumping, drawdowns throughout most of Albuquerque (Figure 6-3) are predicted to be more than 200 feet [including virtually the entire area recently designated as the critical management area or CMA (OSE, 2000)]. Large areas in northwest and east Albuquerque exceed 250 feet of drawdown. The 250-foot drawdown level is the generally accepted level for potential subsidence problems. The amount of water removed from aquifer storage (‘aquifer mining’) by the No Action alternative is estimated to be about 2.0 million ac-ft over the 2006-60 period. Table 6-1 presents pumping, river effects, change in aquifer storage, and SJC use for the No Action and DWP alternatives for the 2006-2060 period.

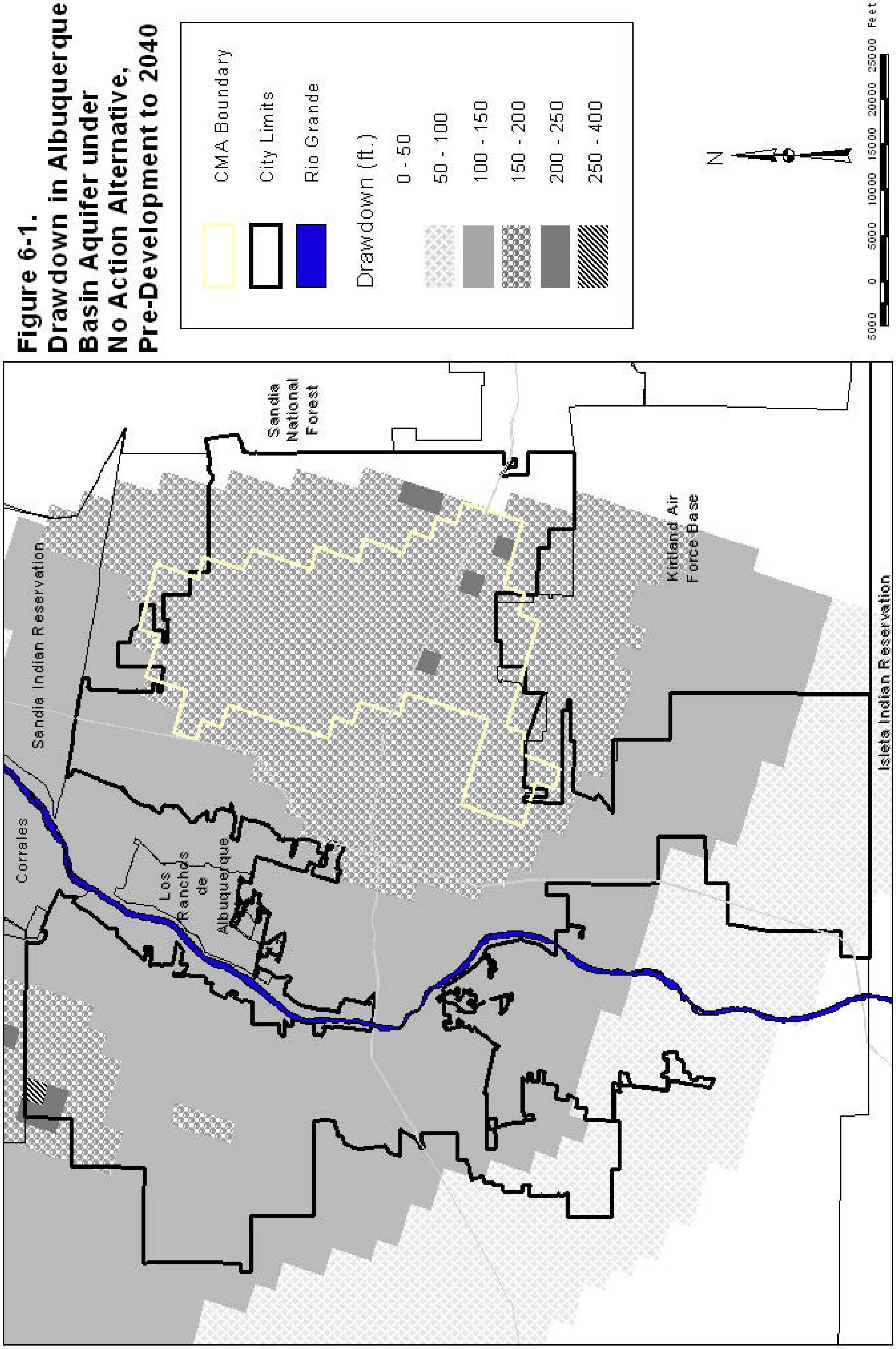

Figure 6-1. Drawdown in Albuquerque Basin Aquifer under No Action Alternative, Pre-Development to 2040

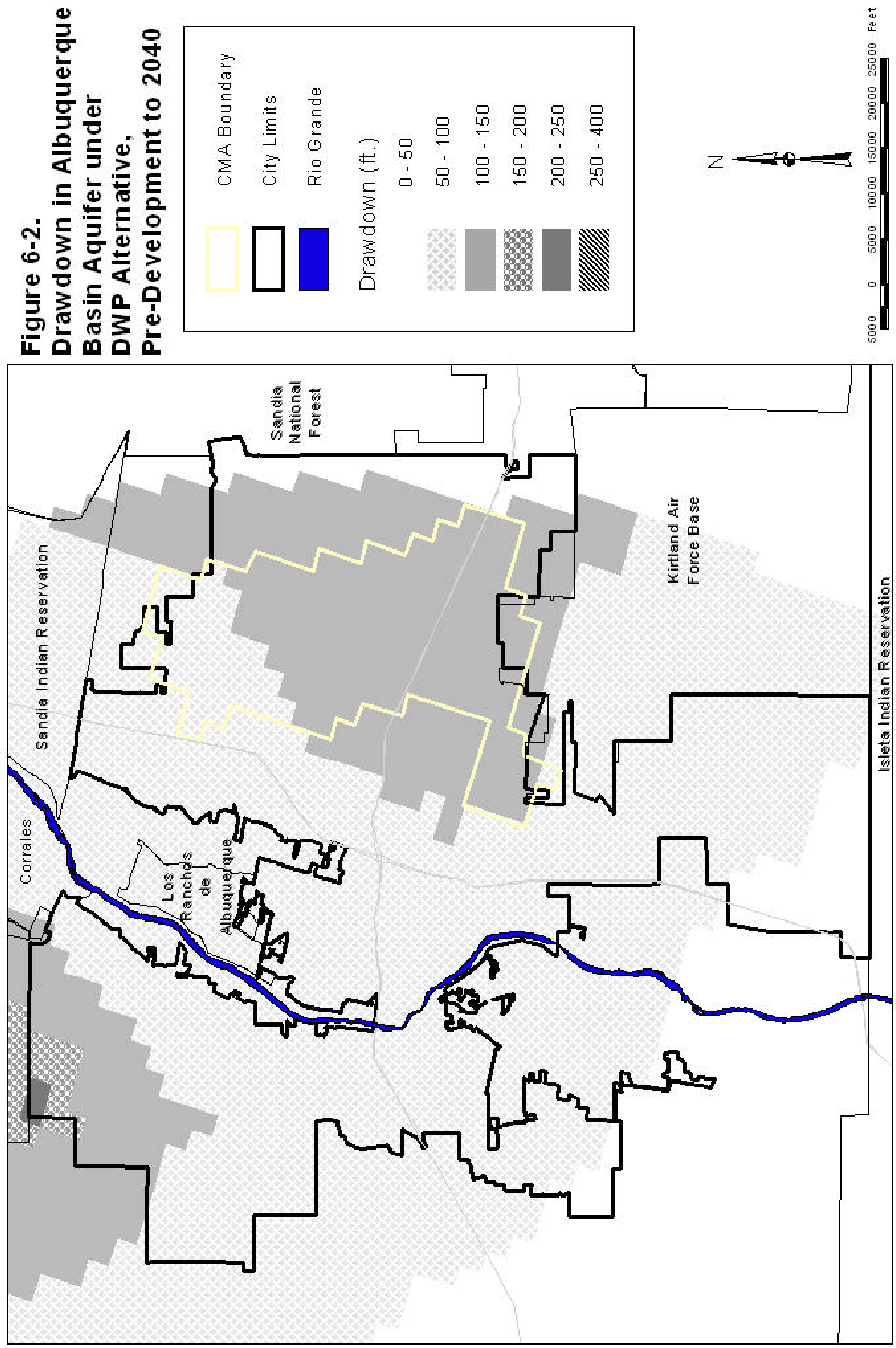

Figure 6-2.
Drawdown in Albuquerque Basin Aquifer under DWP Alternative, Pre-Development to 2040

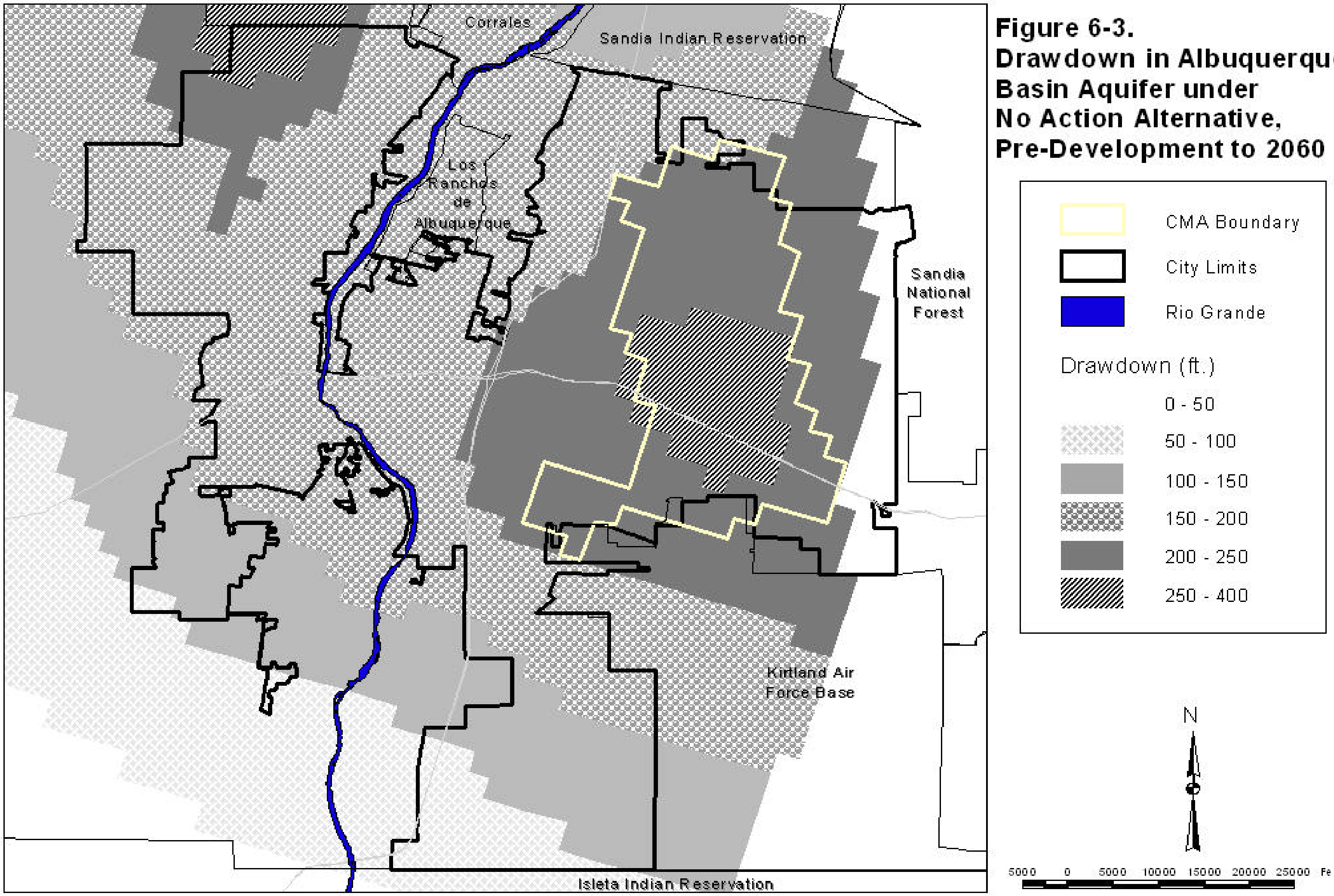

Figure 6-3. Drawdown in Albuquerque Basin Aquifer under No Action Alternative, Pre-Development to 2060

TABLE 6-1
Quantities of Water in Acre-Feet for the Alternatives from 2006 to 2060

	No Action	DWP
Pumping	7,140,000	2,314,000
River Effects	5,007,000	2,457,000
Change in Aquifer Storage	-2,036,000	+192,000
SJC Releases	145,000	2,656,000

Figure 6-4 depicting drawdowns under the DWP alternative in 2060 indicates that most of northeast and southeast Albuquerque will have drawdowns of less than 150 feet. A small area of west Albuquerque is projected to have drawdowns of more than 250 feet. The DWP, as shown above in Table 6-1, results in the addition of 0.19 million ac-ft to aquifer storage through 2060. Thus, relative to the No Action alternative, the DWP would result in the savings of 2.2 million ac-ft of aquifer storage through 2060. This quantity of water is in effect an additional amount of water available to City customers during drought conditions that would not be available without the DWP.

Effects on Riverfront Ground-Water System

The Angostura or new surface diversion options under the DWP alternative should have minimal impact on shallow ground-water levels along their respective riverfront areas. This is based on the fact that the river is in direct hydraulic contact with the adjacent shallow bosque ground-water system; and that shallow ground-water level changes related to DWP-induced flow changes in the Albuquerque reach of ±65 cfs are virtually not measurable. However, implementation of the subsurface diversion alternative would affect the local ground-water system. The subsurface diversion would involve more than a mile of 400- to 500-foot-long perforated pipes (three 11-armed collectors of 400 to 500 feet spaced about 200 feet apart) buried some 15 feet beneath the riverbed upstream and downstream of the Paseo del Norte Bridge. The concern would primarily be on the viability of trees (especially cottonwoods) if the drawdowns became too great.

Figure 6-5, based on a modeling analysis using the MicroFem© model and hydrogeologic data collected along the Rio Grande riverfront by USGS and the City (CH2M HILL, 1999b), indicates that maximum drawdowns in the bosque area will be on the order of 3 to 3.5 feet with the subsurface collectors in operation. Each of the three 11-armed collector systems would cause similar localized drawdowns. By spacing the three systems properly, it appears that mutual interference (and additive drawdowns) can be avoided. Whether or not the projected 3 to 3.5 feet of local drawdowns is an issue for the viability of bosque trees is a question that is under evaluation in the City's DWP EIS.

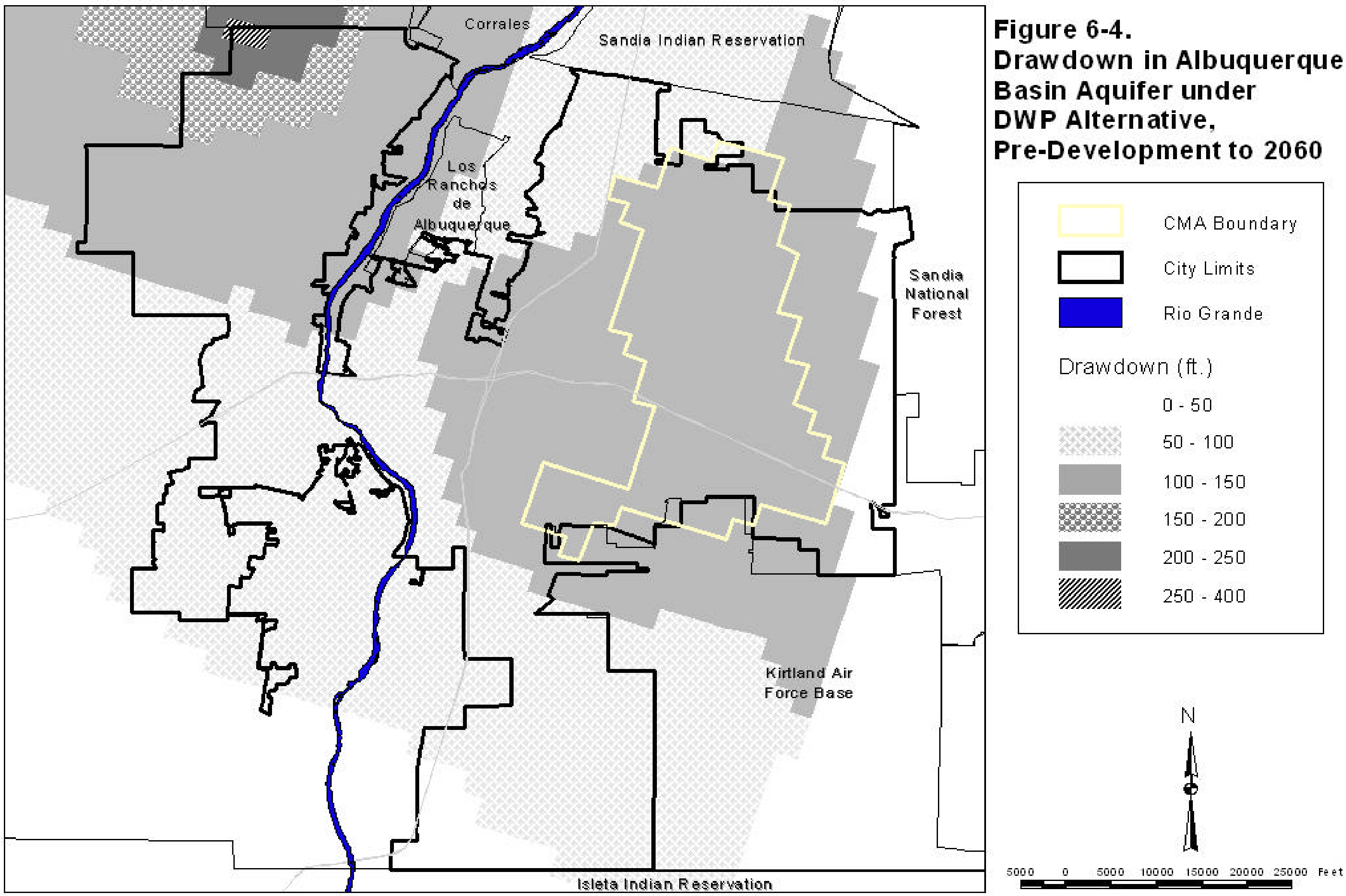

Figure 6-4. Drawdown in Albuquerque Basin Aquifer under DWP Alternative, Pre-Development to 2060

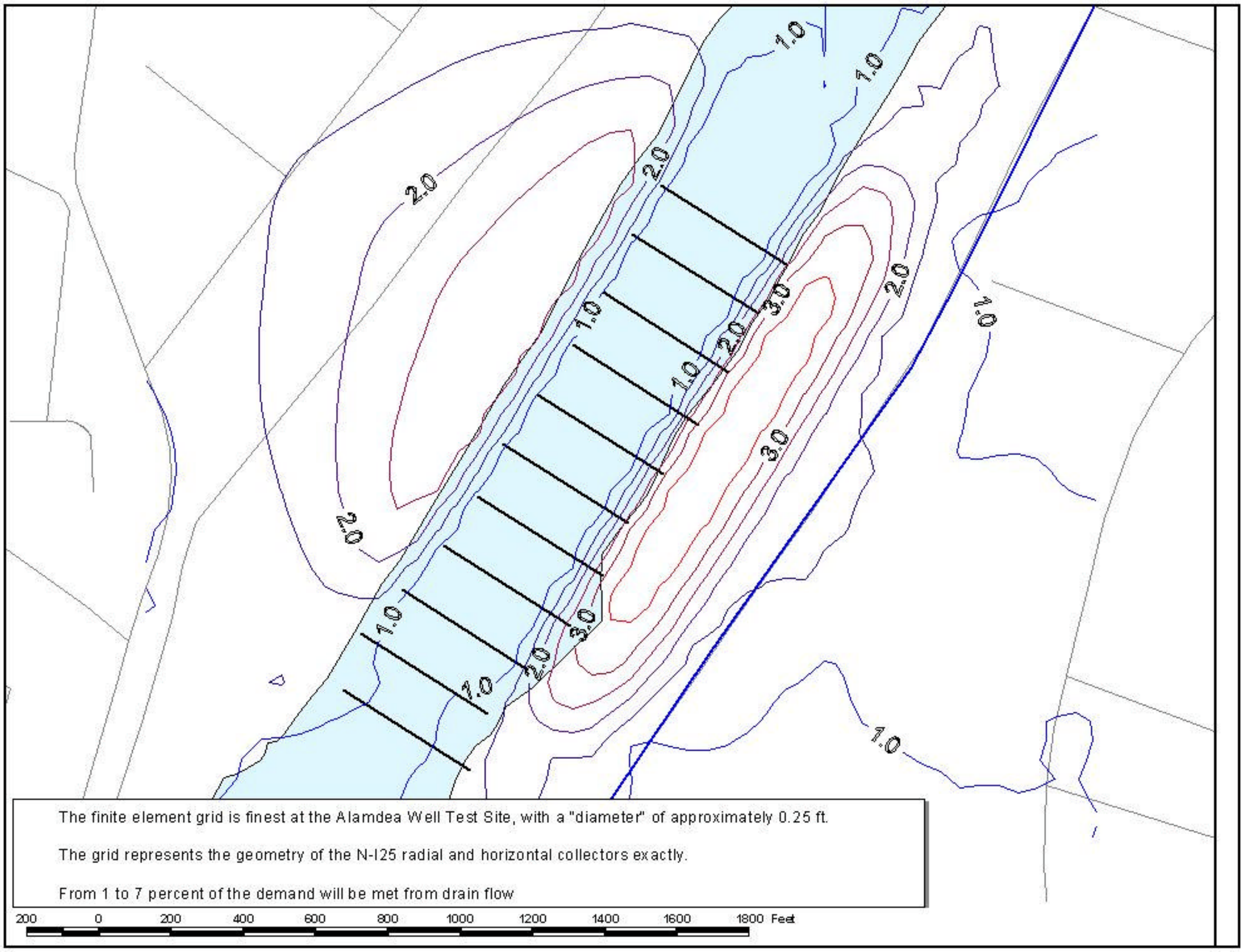

Figure 6-5. Simulated Local Drawdowns of Riverfront Water Table in Vicinity of DWP Subsurface Collection System

It is possible that continued pumping of the deep aquifer under an No Action scenario could, by 2040 or 2060, cause drawdowns of bosque water levels by several feet. However, the scale and time step (yearly) of the OSE interim ground-water model makes simulation of these localized effects problematic.

Section 7

Effects of DWP and No Action Alternatives on the Rio Chama System

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Effects of DWP and No Action Alternatives on the Rio Chama System

To evaluate and compare the effects of the DWP and No Action alternatives on hydrologic conditions in the Rio Chama system, a simplified version of the SJC Riverware© model was used (CH2M HILL, 2001c) based on a computer code developed by the multi-agency Upper Rio Grande Water Operations Model (URGWOM) Team (2000). The model focused on evaluation of effects on flows in the Rio Chama, particularly the capability to maintain historic summertime recreational rafting releases and winter fishery releases. The effects on storage volumes and water levels in El Vado, Abiquiu, and Cochiti Reservoirs also were examined relative to historic conditions (although because of the limited number of years simulated, this evaluation is not considered definitive). DWP simulations were based on a typical pattern of delivery of City SJC water from Heron Reservoir to Abiquiu Reservoir, which is commonly done to minimize evaporative losses while still participating in administrative borrowing and trading for the benefit of the overall SJC system. SJC water for the DWP was simulated as a constant release from the City pool at Abiquiu resulting in a continuous flow of about 66 cfs at Otowi.

For purposes of the SJC Riverware© model, two scenarios were run. The first (the DWP scenario) had the full City allotment of 48,200 ac-ft/yr in the system. An No Action scenario also was evaluated wherein there was no City SJC water in the system. As noted previously, there will, in fact, be limited amounts of City SJC water in the system under No Action for the AWRMS Nonpotable Surface Water Project, for existing leases, and to offset pumpage-induced river effects after about 2050 when vested and acquired rights become inadequate. However, the amounts are so small as to not be reasonably simulated in the SJC Riverware© modeling analysis done for this report. Thus, evaluation of the No Action alternative without City SJC in the system (CH2M HILL, 2001c) brackets the full range of possibilities for purposes of comparing hydrologic effects in the Rio Chama system.

The simulations under the DWP and No Action scenarios assumed full use of individual allocations for other contracted SJC users (i.e., MRGCD, City of Santa Fe, Indian Pueblos) with releases made in accordance with when they were made historically (often, large amounts released at the end of the allocation year); or when they would be made logically given an assumed use (e.g., MRGCD irrigation, Santa Fe Buckman wellfield pumping offsets, etc.). All model runs were made assuming SJC deliveries from Heron Reservoir occurred either within a particular calendar year 'without waivers' or under a scenario 'with waivers', which allows a delay of releases through April of the following calendar year (waivers have been widely used in past years).

Comparisons were made between simulated conditions with the DWP and the No Action alternatives based on the 1971-98 hydrologic record. As was the case for the evaluation of flows at the MRG gaging stations mentioned previously, 1977 and 1988 were chosen as representative of low-flow and normal years, respectively, for simulation by the SJC

Riverware© model. A 3-year drought period was simulated by running 1972 back-to-back three times. Curtailed SJC deliveries (as described previously) occurred during both the 1977 and 3-year drought modeling scenarios. For each of the examined scenarios, computer runs were made with starting reservoir levels at Abiquiu selected as low and high, 50,000 and 170,000 ac-ft, respectively. Similarly, El Vado starting levels were assumed at 80,000 ac-ft (low) and 160,000 ac-ft (high) levels.

Model runs for the Rio Chama system were used to compare the following:

1. Ability to maintain rafting releases in the Rio Chama below El Vado. In recent years, such releases have been based on maintenance of a specified flow during weekdays (600 cfs) and weekends (1,000 cfs) in July and August, normally over a 6-week (7 weekends) period beginning in mid-July.

2. Ability to maintain winter fisheries releases in the Rio Chama below El Vado and Abiquiu. At El Vado, such releases are based on maintenance of a specified minimum flow of 185 cfs in winter months, except during low-flow and drought years when 100 cfs (the release flow during the drought year of 2000-01) has been the specified minimum. Minimum fishery releases below Abiquiu were set at 70 cfs.

3. Reservoir levels — i.e., maximum and minimum volumes and elevations for the DWP and No Action simulations relative to each other and to those experienced during the historic (1971-98) period.

Results of the SJC modeling analysis for rafting and fishery releases are provided in Table 7-1(a) and (b) and are summarized as follows:

- Summertime rafting releases and winter fisheries releases are maintainable under the DWP alternative, either with or without waivers and regardless of initial storage conditions in Abiquiu and El Vado. However, under the No Action scenario, simulations suggest that some of the rafting releases could not be made in low-flow and extended drought years.

- Rafting releases in summer under the DWP scenario mean, in effect, the early delivery of considerable quantities of City SJC water to Abiquiu Reservoir during the peak period of reservoir evaporation. Preliminary evaluation suggests that meeting the historic schedule of rafting releases could cause evaporative losses of several hundred ac-ft/yr in City SJC water available for the DWP. Obviously, the City would need replacement or compensation for such losses to allow a fully operable DWP.

- Regarding reservoir levels, model simulations suggest that the DWP alternative will not markedly change historic maximum and minimum storage volumes and elevations of SJC reservoirs. The simulations based on the three selected periods (normal year, dry year, and 3-year drought) are not sufficient to simulate long-term storage conditions. Consequently, it will take a fully developed URGWOM model and a simulation of long-term (e.g., 50-year) hydrologic record to fully assess the effects of the No Action and DWP alternatives in terms of reservoir levels, shoreline area, depths, etc.

Results of all simulations are provided in the CH2M HILL report (2001c) on the effects of the DWP (and No Action) alternatives on the Rio Chama and Upper Rio Grande.

TABLE 7-1
Comparison of Effects of No Action and DWP Alternatives on Rio Chama System (with waivers)
(a) Rafting Weekends and Minimum Fish Releases – With Waivers

Alternatives	Rafting Weekends	Modeled Rafting Weekends	El Vado Min. Fish Release (cfs)	Modeled El Vado Fish Release (cfs)	Abiquiu Min. Fish Release (cfs)	Modeled Abiquiu Fish Release (cfs)
Dry Year (1977) No Action High Initial Conditions	7	7	100	100	70	70
Dry Year (1977) DWP High Initial Conditions	7	7	100	100	70	70
Dry Year (1977) No Action Low Initial Conditions	7	7	100	100	70	70
Dry Year (1977) DWP Low Initial Conditions	7	7	100	100	70	70
Normal Year (1988) No Action High Initial Conditions	7	7	185	185	70	70
Normal Year (1988) DWP High Initial Conditions	7	7	185	185	70	70
Normal Year (1988) No Action Low Initial Conditions	7	7	185	185	70	70
Normal Year (1988) DWP Low Initial Conditions	7	7	185	185	70	70
3-Year Drought No Action High Initial Conditions	21	17	100	100	70	70
3-Year Drought DWP High Initial Conditions	21	21	100	100	70	70
3-Year Drought No Action Low Initial Conditions	21	16	100	100	70	70
3-Year Drought DWP Low Initial Conditions	21	21	100	100	70	70

TABLE 7-1 (CONTINUED)
Comparison of Effects of No Action and DWP Alternatives on Rio Chama System (without waivers)
(b) Rafting Weekends and Minimum Fish Releases – (Without Waivers)

Alternatives	Rafting Weekends	Modeled Rafting Weekends	El Vado Min. Fish Release (cfs)	Modeled El Vado Fish Release (cfs)	Abiquiu Min. Fish Release (cfs)	Modeled Abiquiu Fish Release (cfs)
Dry Year (1977) No Action High Initial Conditions	7	7	100	100	70	70
Dry Year (1977) DWP High Initial Conditions	7	7	100	100	70	70
Dry Year (1977) No Action Low Initial Conditions	7	5	100	100	70	70
Dry Year (1977) DWP Low Initial Conditions	7	7	100	100	70	70
Normal Year (1988) No Action High Initial Conditions	7	7	185	185	70	70
Normal Year (1988) DWP High Initial Conditions	7	7	185	185	70	70
Normal Year (1988) No Action Low Initial Conditions	7	7	185	185	70	70
Normal Year (1988) DWP Low Initial Conditions	7	7	185	185	70	70
3-Year Drought No Action High Initial Conditions	21	17	100	100	70	70
3-Year Drought DWP High Initial Conditions	21	21	100	100	70	70
3-Year Drought No Action Low Initial Conditions	21	13	100	100	70	70
3-Year Drought DWP Low Initial Conditions	21	21	100	100	70	70

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Appendix A
Supplemental Information on Rio Grande Operational Procedures and River Control Facilities

APPENDIX A

Supplemental Information on Rio Grande Operational Procedures and River Control Facilities

Heron Reservoir

In 1962, Congress authorized the diversion of Colorado River Basin water into the Rio Chama, a tributary to the Rio Grande. The project, operated by USBR, diverts water from three streams in the headwaters of the San Juan River through tunnels in the Continental Divide into Heron Reservoir on the Rio Chama (see Figure 1-1 in main report). Heron Reservoir has a capacity of 400,000 ac-ft and cannot store any water that is native to the Rio Chama. The project is authorized to develop 96,200 ac-ft / yr of SJC water on a 'firm yield' basis, about half of which is for the City of Albuquerque, 25 percent for MRGCD, and the remainder for other users.

The SJC contract provides that the water allotment for any given year be delivered out of Heron Reservoir by December 31. Current USBR policy is to require delivery of the allotment from Heron the same year. However, to the extent that waivers are desirable in the future, USBR may again waive this condition for operational, environmental, and fishery enhancement reasons.

El Vado Reservoir

El Vado Reservoir is owned by the MRGCD and operated by the USBR under an agreement with the MRGCD. El Vado, with a capacity of 186,000 ac-ft, was constructed for water conservation storage. When New Mexico is not in 'debit' status under the Rio Grande Compact, the MRGCD may hold spring runoff flows in El Vado for use to supplement supplies to its irrigators when natural flow in the Rio Grande through the middle valley is low. When New Mexico is in 'debit' status under the Compact, any native water in El Vado up to the amount of the 'debit' must be held for subsequent delivery to Elephant Butte Reservoir. A portion of the water in El Vado is annually reserved to ensure that the prior and paramount irrigation rights of the Pueblos within the MRGCD are met. From the inception of the SJC project, the MRGCD has taken delivery of its SJC water (and through various arrangements) has allowed storage of limited quantities of water for contractors, including the City into El Vado. Storage of imported SJC water in El Vado is not subject to the constraints that exist on native water under the Rio Grande Compact. The outlet works of El Vado were enlarged as part of the SJC project to provide for increased flow from the imported water. Los Alamos County has built a run-of-the-river hydroelectric power generator at the dam.

The Rio Chama has been designated as a Wild and Scenic River downstream of El Vado and into the upper reaches of Abiquiu Reservoir. Accordingly, any changes in the flow patterns in this reach have to take into account environmental and public interest concerns relating to this status.

Abiquiu Reservoir

Abiquiu Reservoir was constructed and is operated for flood and sediment control purposes by the Corps. While the reservoir could hold 1.2 million ac-ft before it spills, the design flood for the reservoir is 500,000 ac-ft. Abiquiu Reservoir is operated to prevent flooding in the Rio Chama (which has a channel capacity of about 1,800 cfs); and, in conjunction with Cochiti and Jemez Reservoirs, to prevent flooding on the Rio Grande. The Corps must pass native water through Abiquiu and release flood storage at all times as fast as downstream conditions permit. However, the operational requirement regarding carryover of stored water at Cochiti (discussed below), is applied to Abiquiu as well. That is, after June 30 when natural flow at Otowi drops below 1,500 cfs, stored flood water in Abiquiu is held until November 1. This 'held' water must be fully evacuated by the following March. The intent of this exception is to prevent downstream diversion of the stored water by irrigators to preserve the pre-reservoir delivery of water for Rio Grande Compact purposes.

In cases where Elephant Butte Reservoir has no additional capacity, the Abiquiu flood protection mandate and operation can extend south of Elephant Butte. Abiquiu Reservoir has authorized sediment pools with an original capacity of 63,000 ac-ft covering an area owned by the United States in fee simple. The land inundated by stored flood water is privately owned, encumbered by easements that allow the land to be flooded as necessary for flood control operations.

Since 1974, the City arranged with the Corps to store SJC water within the sediment pool. In 1981 Congress authorized the storage of 200,000 ac-ft of SJC water in Abiquiu (*PL 97-140*). Under an agreement with the Corps, the City can store up to 170,900 ac-ft of SJC water in Abiquiu. This water is held within the 500,000 ac-ft flood pool, and the City has acquired leases from private lakefront property owners to allow this storage. In the event of a design flood, the Corps may pre-spill stored SJC water if necessary for its flood control operations.

In *PL 100-522*, Congress authorized storage of native water in Abiquiu when it was no longer needed for storage of SJC water. Such storage would face the same Rio Grande Compact restrictions that apply to El Vado. The City has filed an application with the State Engineer for storage of native water in Abiquiu.

Cochiti Reservoir

Cochiti Reservoir, with a capacity of 500,000 ac-ft, was built by the Corps for flood and sediment control. In addition, Congress authorized a recreation pool for fish and wildlife enhancement through dedication of 5,000 ac-ft/yr of SJC water to maintain a pool of about 50,000 ac-ft.

The limiting-channel capacity below Cochiti is about 7,000 cfs. When this capacity is used for flood releases, no SJC water may be delivered. The flood control criteria on Cochiti are similar to Abiquiu. Flood water must be passed as soon as possible, except that flood water in storage must be carried to November 1 following the drop of the natural flow at Otowi gage to below 1,500 cfs after June 30, *if there is at least 212,000 ac-ft of space in Cochiti for regulation of summer floods*. This requirement can be waived with the consent of the Rio Grande Compact Commission and in emergency situations.

Elephant Butte Reservoir

Elephant Butte Reservoir, with a capacity of 2.2 million ac-ft, is a USBR-constructed facility used to store water for downstream use in New Mexico and Texas and to assure delivery of required water to Mexico. In the 1970s, Congress authorized creation of a 50,000 ac-ft recreation pool in Elephant Butte and its maintenance for 10 years using SJC water. The pool was intended to allow for recreation coincident with full use of stored native water by downstream users in dry periods. To maintain the pool after the initial 10 years, the State of New Mexico contracted with the City to maintain the pool through 2010. Due to successive wet years, the pool has spilled twice, the last time in 1994, but will be recreated as needed. The City has a contract with USBR to store an additional 50,000 ac-ft of City water in Elephant Butte and had small amounts stored under this agreement before Elephant Butte spilled in 1985. Since then, either because storage space was not available or its use was not needed, this storage has not been used.

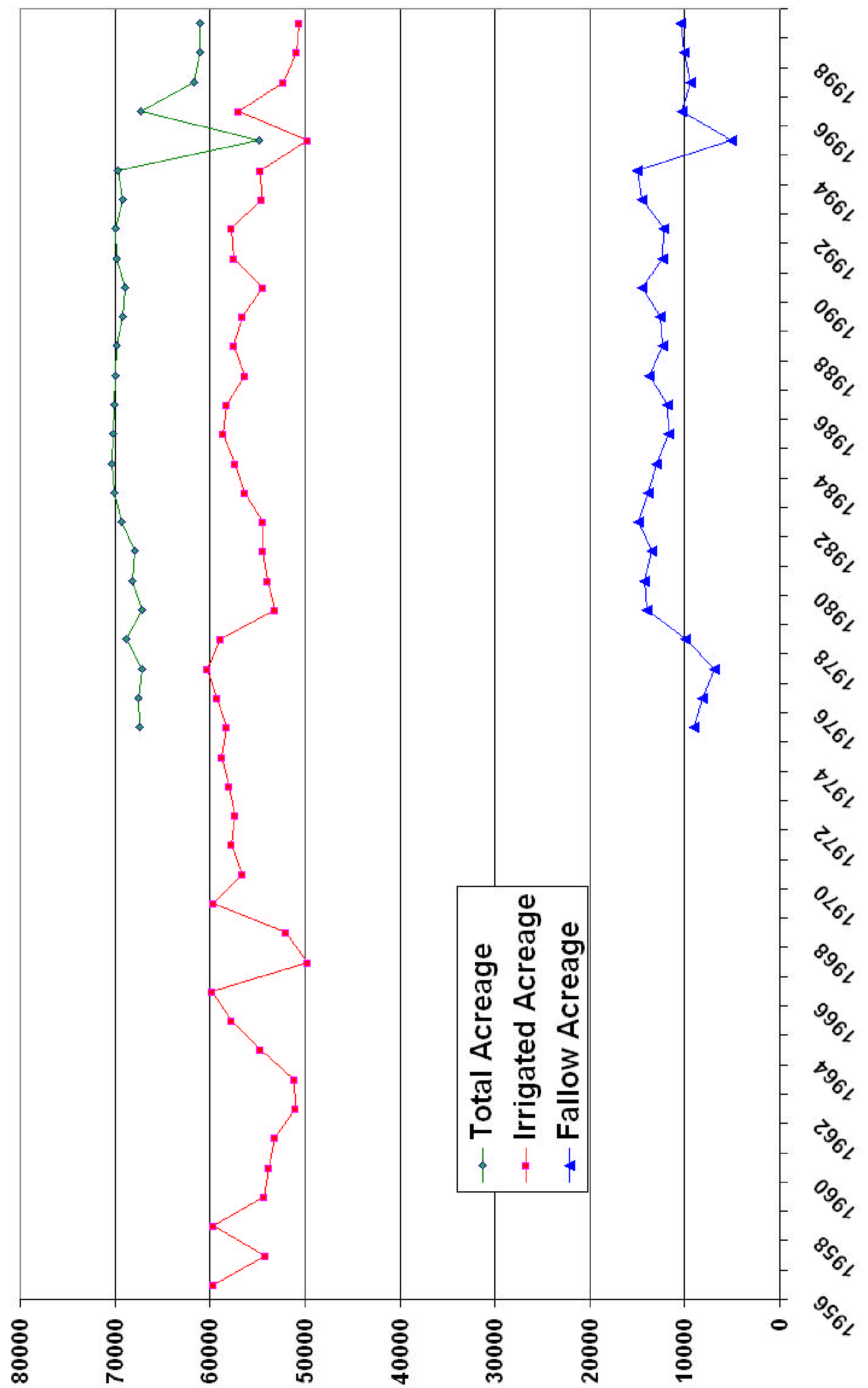
Diversion Dams

Water is diverted into irrigation canals at Cochiti Dam and at three downstream low-head diversion dams built solely for that purpose. The Cochiti diversion is located 31 miles north of Albuquerque; Angostura 15 miles north of Albuquerque; Isleta 10 miles south of Albuquerque; and San Acacia 14 miles north of Socorro. Water outside the river channel flows through more than 800 miles of canals and channels maintained by the MRGCD.

MRGCD Croplands

Historic records of MRGCD croplands are not available on a consistent, accurate basis. Figure A-1 shows the estimated total, irrigated, and fallow acreages developed by the URGWOM team (Bill Miller, November 2000, written communication) during recent investigations. Until the mid-1990s, it appears total MRGCD acreage was fairly constant at just less than 70,000 acres. Of that total 55,000 to 60,000 acres was actually irrigated and the remainder in fallow. Since about the mid-1990s, it would appear the total MRGCD acreage is trending down toward 60,000 acres with a corresponding downward trend in irrigated and fallow to about 50,000 and 10,000 acres, respectively.

Figure A-1. MRGCD Acreages, 1956-99



Regarding the historic distribution of MRGCD acreages amongst the Cochiti, Albuquerque, Belen, and Socorro Divisions, only generalized data are available; estimated that total acreages in the various divisions were about as follows:

- Cochiti — 6,300 acres
- Albuquerque — 12,000 acres
- Belen — 33,000 acres
- Socorro — 12,800 acres

Low-Flow Conveyance Channel

The LFCC between San Acacia and Elephant Butte Reservoir was designed and built to minimize seepage and evaporation losses in the main channel of the river below the San Acacia diversion dam during low-flow periods. The USBR built the LFCC in the 1950s when the river channel was closed in four places by the intrusion of vegetation and a prolonged drought, which had left little water in Elephant Butte Reservoir. The LFCC, and a new river channel, were constructed to the 'narrows' section of Elephant Butte to which (and below) the reservoir had receded during the prolonged drought of the 1950s. The more efficient conveyance of water in the LFCC increased New Mexico's ability to satisfy its Compact obligations to Texas and helped the United States to meet its Treaty obligations to Mexico.

While all the required flow, weather, and other monitoring devices are not available to do a detailed annual accounting of the water actually salvaged by the LFCC system, it would appear that 40,000 and 50,000 ac-ft/yr is a reasonable estimate.

The lower 35 miles of the LFCC were put into operation in the early 1950s and the upper 40 miles in 1958. Originally, the LFCC was intended to carry up to 2,000 cfs, but not all of this capacity was available for water diverted at San Acacia. In the lower reaches of the LFCC, about 400 cfs of the capacity was occupied by water that enters the channel through seepage and irrigation return flows. Hence, operationally, the original LFCC could (in early year operations) handle about 1,600 cfs of flow diverted at San Acacia.

In 1975 the LFCC was truncated by about one-half, with water returning to the river channel at Tiffany Junction near San Marcial. In 1981, the remaining LFCC went out of operation as Elephant Butte Reservoir filled and inundated the lower reaches of the LFCC virtually to San Marcial. The channel subsequently operated for a short time, but was impaired by 1985 due to the deposition of sediment. Since 1985, the LFCC system below San Acacia has functioned primarily as a drain with maximum flows of several hundred cubic feet per second rather than several thousand. Consequently, since 1985 the floodway (or natural channel) of the Rio Grande has conveyed the vast majority of water passing San Acacia and San Marcial.

In 1996, the USBR constructed a connection between the LFCC and the river channel about 10 miles below the San Acacia diversion dam. Currently, both the USBR and the Corps have undertaken studies to evaluate the options regarding the future of the LFCC.

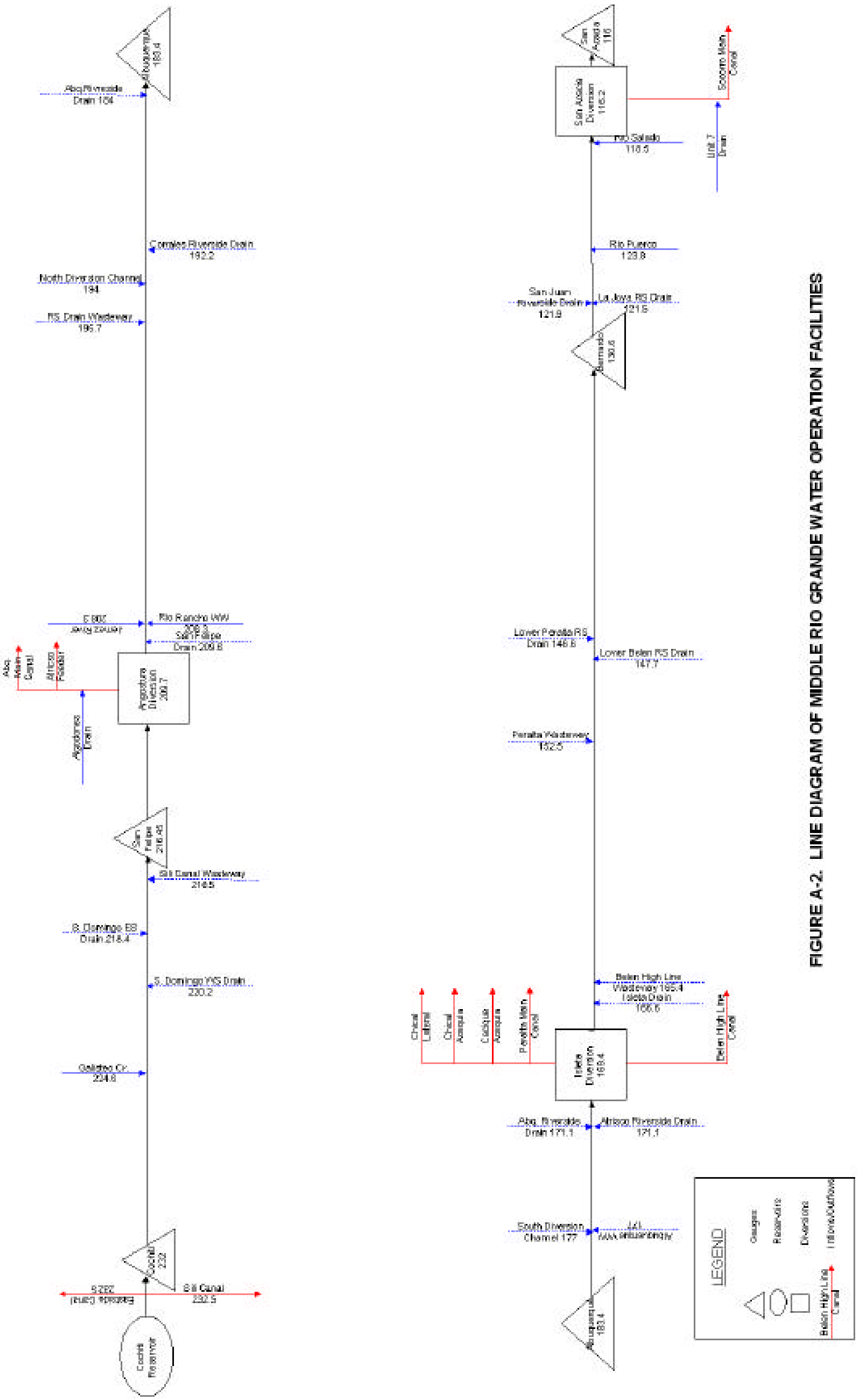


FIGURE A-2. LINE DIAGRAM OF MIDDLE RIO GRANDE WATER OPERATION FACILITIES

Appendix B

Historical Data on Imported San Juan-Chama Water

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Sum	Mean Monthly
1971	0	0	0	0	6,040	5,380	0	3,270	0	0	0	0	14,690	1,224
1972	0	0	0	0	2,710	5,520	8,050	4,110	120	10	30	30	20,580	1,715
1973	0	0	20	0	20	0	20	20	20	20	2,210	60	2,390	199
1974	0	60	40	410	0	240	8,790	24,050	160	270	0	100	34,120	2,843
1975	0	0	0	34,520	0	0	2,950	390	410	11,100	0	40,840	90,210	7,518
1976	18,500	0	0	1,960	0	620	600	740	660	350	280	4,880	28,590	2,383
1977	0	0	470	3,520	11,120	6,460	23,880	6,420	10,580	12,080	190	10,440	85,160	7,097
1978	17	16	199	1,487	548	1,088	9,731	4,819	4,104	109	113	6,734	28,965	2,414
1979	-115	-129	-336	-7,308	9	5	61	388	656	779	-119	10,132	4,023	335
1980	-122	-138	3,048	187	-1	-11	14,529	18,363	15,716	9,880	-58	1,687	63,080	5,257
1981	5,323	277	185	2,175	2,475	29,257	24,787	11,040	1,901	966	992	5,679	85,057	7,088
1982	82	-95	-115	3,947	-138	328	3,638	362	463	443	-12	6,605	15,508	1,292
1983	463	37	475	1,941	-61	-13	3,203	8,126	20,352	4,146	4,531	1,513	44,713	3,726
1984	1,161	220	-761	2,324	-24	568	3,665	15,401	18,520	310	1,444	5,451	48,279	4,023
1985	7,787	484	394	2,843	-3	-6	-35	-107	-197	284	28	679	12,151	1,013
1986	-28	22,072	44,423	-12	-9	-6	516	5,042	-188	191	56	781	72,838	6,070
1987	-14	549	-31	-67	-51	-121	-112	8,676	16,417	13,598	4,200	49	43,093	3,591
1988	49	-138	868	-50	106	-20	1,161	581	751	1,249	4,508	-11	9,054	755
1989	-97	2	286	1,179	3,698	6,816	39,033	28,249	14,549	123	918	4,420	99,176	8,265
1990	846	115	1,650	447	100	2,728	2,814	11,180	28,876	1,596	160	846	51,358	4,280
1991	638	598	257	392	-437	2,032	22,373	6,255	14,574	15,401	344	4,898	67,325	5,610
1992	6,398	6,123	23,681	9,329	-3	3,271	1,694	1,404	38,302	26,524	1,024	3,354	121,101	10,092
1993	2,617	524	1,905	-293	-452	3	9,110	5,416	4,491	10,705	254	1,987	36,267	3,022
1994	6,766	3,942	2,799	751	-190	979	10,496	6,624	10,742	19,957	-531	2,465	64,800	5,400
1995	2,556	3,446	3,377	367	-407	3	2,440	8,784	17,557	22,450	343	1,759	62,675	5,223
1996	1,218	-236	1,027	9,514	5,044	18,682	30,661	33,797	27,490	16,037	1,387	3,111	147,732	12,311
1997	1,445	4,989	3,180	1,912	-1,777	11	11,948	1,263	11,412	107	361	1,653	36,504	3,042
1998	1,512	758	1,852	4,701	-320	16,519	11,976	6,001	38,032	11,324	912	1,836	95,103	7,925
Mean	2,036	1,553	3,175	2,721	1,000	3,583	8,856	7,881	10,588	6,429	842	4,356	53,019	4,418

TABLE B-1. TOTAL SJC FLOWS AT OTOWI, 1971-1998 (AC-FT)

Water Accounting\SJC_Otowi

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Sum	Mean Monthly
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	1,945	3,962	5,778	2,950	86	7	22	22	14,771	1,231
1973	0	0	1	0	1	0	1	1	1	1	119	3	129	11
1974	0	1	0	4	0	3	96	262	2	3	0	1	372	31
1975	0	0	0	329	0	0	28	4	4	106	0	389	860	72
1976	793	0	0	84	0	27	26	32	28	15	12	209	1,226	102
1977	0	0	115	860	2,718	1,579	5,837	1,569	2,586	2,953	46	2,552	20,816	1,735
1978	0	0	1	5	2	4	34	17	14	0	0	23	100	8
1979	-3	-3	-8	-182	0	0	2	10	16	19	-3	252	100	8
1980	0	0	863	53	0	0	4,114	5,199	4,450	2,797	0	478	17,954	1,496
1981	2,567	134	89	1,049	1,194	14,110	11,954	5,324	917	466	478	2,739	41,021	3,418
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	416	0	0	0	0	0	0	0	0	0	0	0	416	35
1984	1,160	0	0	0	0	0	0	4,347	0	0	0	0	5,507	459
1985	2,299	0	0	0	0	0	0	0	0	0	0	453	2,752	229
1986	0	2,710	18,801	0	0	0	0	0	0	0	0	170	21,682	1,807
1987	0	612	0	0	0	0	0	793	7,843	8,973	754	120	19,095	1,591
1988	0	0	0	0	0	0	99	43	33	14	3,659	70	3,918	327
1989	0	0	25	1,100	4,152	758	4,997	2,508	1,257	11	801	2,797	18,405	1,534
1990	1,181	38	1,748	568	473	993	1,659	15,028	17,106	649	192	558	40,194	3,350
1991	212	199	85	130	0	2,695	18,009	2,081	5,763	7,633	114	6,345	43,267	3,606
1992	8,467	8,307	30,949	10,947	0	1,372	564	553	12,742	8,824	1,276	3,222	87,223	7,269
1993	3,545	891	634	0	0	1	8,459	1,802	1,494	3,561	84	1,758	22,230	1,852
1994	8,821	4,686	3,357	993	0	326	3,492	2,204	3,574	6,639	0	1,351	35,441	2,953
1995	3,404	4,491	1,123	134	0	1	947	4,700	5,841	7,468	165	585	28,860	2,405
1996	405	0	815	4,216	1,863	6,255	10,891	11,243	9,145	5,794	1,569	3,166	55,363	4,614
1997	2,050	2,393	4,788	890	0	4	4,084	420	3,796	36	490	1,290	20,241	1,687
1998	503	252	1,447	6,392	0	16,506	11,623	7,144	16,362	3,767	350	611	64,957	5,413
Mean	1,279	883	2,315	985	441	1,736	3,310	2,437	3,324	2,133	362	1,042	20,246	1,687

TABLE B-2. CITY SJC FLOWS AT OTOWI, 1971-1998 (AC-FT)

Water Accounting\SJC_Otowi_ABQ

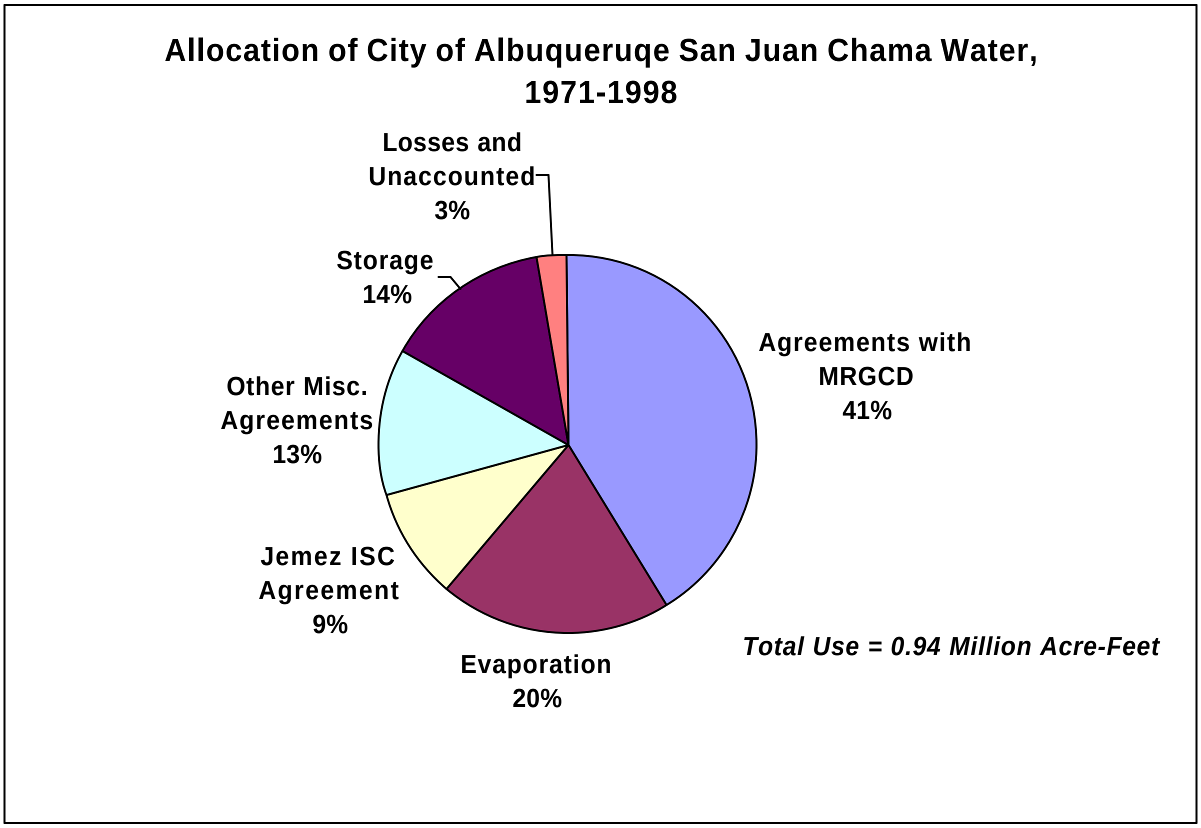
Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Sum	Mean Monthly
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	1,461	2,975	4,339	2,215	65	5	16	16	11,092	924
1973	0	0	1	0	1	0	1	1	1	1	113	3	123	10
1974	0	1	0	4	0	2	91	249	2	3	0	1	353	29
1975	0	0	0	313	0	0	27	4	4	101	0	370	817	68
1976	754	0	0	80	0	25	24	30	27	14	11	199	1,165	97
1977	0	0	87	650	2,055	1,194	4,412	1,186	1,955	2,232	35	1,929	15,734	1,311
1978	0	0	1	5	2	4	32	16	13	0	0	22	95	8
1979	0	0	0	0	0	0	1	9	15	18	0	239	284	24
1980	0	0	648	40	0	0	3,090	3,905	3,342	2,101	0	359	13,486	1,124
1981	1,927	100	67	787	896	10,589	8,972	3,996	688	350	359	2,055	30,786	2,566
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	395	0	0	0	0	0	0	0	0	0	0	0	395	33
1984	1,102	0	0	0	0	0	0	4,129	0	0	0	0	5,232	436
1985	2,184	0	0	0	0	0	0	0	0	0	0	430	2,614	218
1986	0	1,537	0	0	0	0	0	0	0	0	0	162	1,699	142
1987	0	571	0	0	0	0	0	595	5,222	8,276	639	113	15,417	1,285
1988	0	0	0	0	0	0	94	41	31	14	451	0	631	53
1989	0	0	19	68	3,881	442	2,530	1,894	943	8	746	2,581	13,110	1,092
1990	1,066	29	1,551	510	443	762	1,389	8,486	5,490	510	172	474	20,882	1,740
1991	159	149	64	98	0	490	6,630	1,561	4,505	6,227	86	5,702	25,670	2,139
1992	7,618	7,484	27,826	5,884	0	1,086	423	432	9,556	6,618	1,144	1,508	69,579	5,798
1993	3,194	811	475	0	0	1	2,205	1,351	1,121	2,671	63	1,538	13,431	1,119
1994	6,720	2,612	674	893	0	244	2,619	1,653	2,680	4,979	0	598	23,673	1,973
1995	616	1,314	0	103	0	1	590	2,117	4,380	5,601	134	439	15,294	1,275
1996	304	0	250	2,446	1,221	4,504	7,389	8,432	6,859	3,860	332	901	36,498	3,041
1997	347	1,516	761	475	0	3	3,084	315	2,847	27	87	572	10,034	836
1998	377	189	465	1,131	0	14,582	10,245	6,388	13,014	2,825	272	458	49,945	4,162
Mean	956	583	1,175	482	356	1,318	2,078	1,750	2,241	1,659	166	738	13,501	1,125

TABLE B-3. MONTHLY CITY SJC FLOWS AT ALBUQUERQUE, 1971-1998 (AC-FT)

Water Accounting\SJC_ABQ

TABLE B-4. AGGREGATE SUMMARY OF DISPOSITION OF CITY SJC WATER, 1971-98 (AC-FT)

City SJC Water Released from Heron	937,638
City SJC Water Provided to MRGCD through Ageements	386,615
City SJC Water Evaporative Losses (primarily Abiquiu)	185,774
City SJC Water Provided to Jemez Reservoir through ISC Agreement	88,767
City SJC Used for Other Miscellaneous Agreements	117,324
City SJC Water in Storage (end of 1998)	135,119
Losses and Unaccounted for Water	24,039



Water Accounting \ Table 5 (2)

Appendix C

Historical Data on Rio Grande Streamflows at Major Gaging Stations

Middle Rio Grande Streamflow Stations

Gaging Station	Historical Data
Rio Grande at Embudo (8279500)	1889 to present (above all San Juan and Chama inflows)
Rio Grande at Otowi Bridge (831300)	1895 to present (includes San Juan and Chama inflows)
Rio Grande at Cochiti (8314500)	1926-1970
Rio Grande below Cochiti Lake (8317400)	1971 to present (includes flow of Santa Fe River)
Sili Main Canal at Cochiti (8317400)	1954 to present
Cochiti East Side Main Canal at Cochiti (8313500)	1954 to present
Galisteo Creek below Galisteo (8317900)	1970 to present
Rio Grande at San Felipe (0831900)	1926 to present
Jemez River below Jemez Canyon Dam (832900)	1943 to present
Rio Grande near Bernalillo (8329500)	1941-1969
North Floodway Channel (8329900)	1968 to present
Rio Grande at Albuquerque (833000)	1941 to present
South Diversion Channel (8330775)	1968 to present
City of Albuquerque Wastewater Returns	Estimated early 1970s to 1980s; more recently metered
Rio Grande near Belen (8331500)	1941-1957
Lower San Juan Riverside Drain near Bernardo (8332030)	1954-1975
Rio Grande near Bernardo (8332000)	1941-64 (measured total Rio Grande flow)
Rio Grande Floodway near Bernardo (8332010)	1964 to present (must add to 8331980 for total)
Rio Grande Conveyance Channel near Bernardo (8331980)	1964 to present (add to 8332010 for total)
Bernardo Interior Drain near Bernardo (8332050)	1964 to present
Rio Puerco near Bernardo (8353000)	1939 to present
Rio Salado near San Acacia (8354000)	1947-1984
Socorro Main Canal North at San Acacia (8354500)	1936-1964: 1964 to present
Rio Grande at San Acacia (835500)	1936-64 (prior to 1958, gage measured total Rio Grande flow; from 1958-64, included LFCC flow; after 1964 add 08354800 and 8354900 to get total)
Rio Grande Conveyance Channel at San Acacia (8354800)	1964 to present (LFCC constructed in 1958; from 1958-64, LFCC flow included w/ 835500)
Rio Grande Floodway at San Acacia (8354900)	1964 to present (add with 8354800); after 1964 to get total flow of Rio Grande at San Acacia
Rio Grande at San Marcial (8358500)	1895-1964 (measured total Rio Grande flow)
Rio Grande Conveyance Channel at San Marcial (8358300)	1969 to present (add to 8358400 for total)
Rio Grande Floodway at San Marcial (8358400)	1964 to present (add to 8358300 for total)

Year	January Average (cfs)	February Average (cfs)	March Averge (cfs)	April Average (cfs)	May Average (cfs)	June Average (cfs)	July Average (cfs)	August Average (cfs)	September Average (cfs)	October Average (cfs)	November Average (cfs)	December Average (cfs)	**Annual Average (cfs)**
1900	598	582	859	866	3,440	2,914	297	165	716	387	425	472	**977**
1901	397	658	742	1,403	5,195	2,201	729	827	580	491	462	463	**1,179**
1902	482	489	548	1,640	1,196	474	272	556	484	279	309	313	**587**
1903	376	445	1,223	2,896	6,612	11,927	2,225	432	375	355	457	423	**2,312**
1904	382	477	401	536	443	324	246	935	1,000	3,226	773	515	**772**
1905	503	734	2,571	3,679	12,771	9,622	873	618	286	318	501	483	**2,746**
1910	608	563	3,251	5,119	6,929	2,194	179	360	264	379	568	525	**1,745**
1911	775	748	1,486	2,516	6,627	5,725	5,692	1,341	1,080	5,475	2,222	1,258	**2,912**
1912	790	744	1,537	2,332	9,813	8,537	1,549	740	488	622	643	528	**2,360**
1913	480	570	796	2,460	2,918	1,883	464	273	434	915	829	572	**1,049**
1919	581	605	1,402	5,293	9,275	3,382	2,574	1,012	606	867	901	880	**2,282**
1920	789	1,350	1,396	2,382	12,429	10,401	2,698	995	626	760	1,050	787	**2,972**
1921	740	848	1,654	1,215	4,212	9,435	2,275	2,092	1,207	771	889	871	**2,184**
1922	780	906	1,238	1,808	6,015	6,195	1,093	355	294	355	610	686	**1,695**
1923	721	844	925	1,604	5,919	4,382	1,042	1,333	1,973	2,245	1,639	1,141	**1,981**
1924	818	1,197	1,369	6,190	10,409	3,131	993	483	326	479	612	632	**2,220**
1925	600	902	1,296	2,545	1,940	807	693	932	716	1,079	1,041	937	**1,124**
1926	811	821	1,229	2,450	7,260	4,450	1,000	430	380	406	580	644	**1,705**
1927	667	792	1,086	3,180	7,087	3,765	3,020	797	3,000	2,134	1,213	864	**2,300**
1928	825	853	1,223	1,623	5,643	2,277	304	401	258	340	548	507	**1,233**
1929	580	690	1,033	2,020	5,654	3,102	844	2,638	2,495	1,696	1,235	918	**1,909**
1930	785	1,065	1,002	3,755	2,521	1,623	1,071	1,094	453	661	691	652	**1,281**
1931	596	836	1,043	1,198	2,013	648	352	368	975	1,025	617	756	**869**
1932	638	1,088	2,122	5,495	8,741	4,978	2,325	676	527	570	759	660	**2,382**
1933	686	693	967	992	2,872	3,285	757	491	526	492	515	663	**1,078**
1934	670	836	714	1,178	706	274	220	236	385	316	343	460	**528**
1935	556	563	473	938	3,268	6,102	1,436	1,368	1,072	888	926	660	**1,521**
1936	591	793	1,070	4,183	3,827	1,343	1,002	1,264	1,017	904	995	732	**1,477**
1937	591	1,175	2,035	5,381	8,504	3,742	1,637	1,317	1,162	679	569	567	**2,280**
1938	577	700	834	2,322	5,349	4,594	2,058	1,572	1,072	1,155	916	831	**1,832**
1939	717	702	2,226	2,544	1,968	1,214	1,118	770	528	435	348	447	**1,085**
1940	492	577	753	919	1,282	1,156	1,097	772	883	586	546	593	**805**
1941	598	933	1,354	2,164	14,585	10,239	3,909	1,443	1,176	2,685	2,421	1,266	**3,565**
1942	986	980	1,877	7,329	10,991	7,354	1,547	1,190	1,167	750	547	706	**2,952**
1943	676	771	783	1,680	1,499	1,472	1,091	1,054	859	619	548	586	**970**
1944	569	713	957	1,203	6,611	5,202	1,882	1,331	1,019	705	637	685	**1,793**
1945	674	890	831	1,580	7,051	2,556	1,210	1,054	934	703	631	558	**1,556**
1946	573	624	640	796	783	986	497	462	316	437	1,304	1,437	**738**
1947	575	700	667	846	2,458	1,152	1,028	974	491	687	1,847	1,206	**1,052**
1948	633	770	1,057	2,870	5,103	6,202	899	812	480	401	516	606	**1,696**
1949	590	1,380	2,217	1,726	3,822	6,229	2,581	823	738	596	647	673	**1,835**
1950	720	2,191	1,860	1,103	650	939	697	633	393	376	355	475	**866**
1951	510	1,080	477	376	824	859	536	504	221	235	344	492	**538**
1952	759	602	1,046	2,798	6,161	5,638	2,410	1,774	492	402	509	656	**1,937**
1953	685	852	957	1,036	1,080	1,937	415	404	191	285	465	516	**735**
1954	498	689	598	930	1,551	626	596	273	448	311	323	380	**602**
1955	463	493	549	366	1,443	803	503	893	614	267	363	469	**602**
1956	546	535	683	999	934	624	297	269	255	168	281	361	**496**
1957	402	551	490	1,166	3,538	5,053	4,333	3,308	1,771	943	1,665	948	**2,014**
1958	739	991	1,153	4,073	8,740	3,949	517	855	667	389	1,632	1,251	**2,080**
1959	600	656	605	670	972	429	418	539	290	497	778	583	**586**
1960	567	592	1,513	3,218	2,159	2,320	511	435	437	382	609	499	**1,104**
1961	461	630	714	1,406	3,054	1,278	574	878	694	527	1,654	1,137	**1,084**
1962	668	1,182	1,146	4,192	3,802	1,482	586	444	451	382	1,528	1,468	**1,444**
1963	664	807	1,194	1,668	578	288	212	260	253	236	573	355	**591**
1964	429	454	566	698	1,437	449	302	472	366	234	672	425	**542**
1965	691	696	823	2,208	4,155	4,520	3,000	1,262	804	1,041	1,776	1,903	**1,907**
1966	882	864	1,748	2,370	2,491	1,192	391	696	275	303	1,195	729	**1,095**
1967	570	678	787	509	1,071	1,090	479	1,578	627	344	1,044	611	**782**
1968	629	700	931	1,039	2,660	2,895	764	2,129	391	354	1,222	593	**1,192**
1969	842	786	915	2,412	3,756	3,477	1,022	964	877	1,360	1,572	1,302	**1,607**
1970	822	966	971	1,154	2,677	2,030	684	416	1,070	787	1,420	772	**1,147**

1900-1970 Summary

Minimum	376	445	401	366	443	274	179	165	191	168	281	313	**496**
Maximum	986	2,191	3,251	7,329	14,585	11,927	5,692	3,308	3,000	5,475	2,421	1,903	**3,565**
Mean	633	800	1,139	2,214	4,508	3,377	1,226	900	725	785	868	727	**1,492**
Median	604	746	1,018	1,703	3,647	2,438	886	804	554	512	645	648	**1,363**
Std. Dev.	132	277	557	1,542	3,425	2,886	1,099	596	524	842	501	318	**733**

TABLE C-1. MONTHLY RIO GRANDE FLOWS AT OTOWI, 1900-1970

Append B All Gages\Table C-1Otowi

Year	January Average (cfs)	February Average (cfs)	March Averge (cfs)	April Average (cfs)	May Average (cfs)	June Average (cfs)	July Average (cfs)	August Average (cfs)	September Average (cfs)	October Average (cfs)	November Average (cfs)	December Average (cfs)	**Annual Average (cfs)**
1971	721	877	1,141	1,215	898	528	568	463	396	910	1,151	735	**800**
1972	688	862	1,274	741	433	470	394	391	449	689	1,020	734	**679**
1973	685	692	1,161	1,851	5,514	4,909	3,125	1,612	1,033	845	922	1,681	**2,003**
1974	1,326	717	1,161	936	1,032	1,031	668	769	263	361	429	450	**762**
1975	473	562	956	2,078	3,680	4,023	2,681	968	976	821	1,485	1,959	**1,722**
1976	1,046	695	897	1,342	2,611	1,430	1,168	1,009	979	470	434	510	**1,049**
1977	436	526	612	489	639	1,162	838	633	467	493	401	488	**599**
1978	445	500	671	877	2,830	2,419	1,110	811	536	441	686	672	**1,000**
1979	565	649	1,683	3,506	6,616	7,914	3,579	1,169	741	819	1,618	1,477	**2,528**
1980	677	866	1,018	2,570	6,351	5,943	1,954	786	545	490	1,296	1,391	**1,991**
1981	688	590	631	606	833	956	735	642	415	564	740	581	**665**
1982	558	659	1,064	2,087	4,105	4,125	1,425	1,189	1,547	1,026	1,009	878	**1,639**
1983	746	954	1,475	2,480	5,054	6,162	3,087	952	704	527	589	1,036	**1,980**
1984	717	730	1,462	3,060	6,786	4,601	1,038	895	722	732	1,026	1,025	**1,900**
1985	993	1,021	2,346	6,412	8,390	6,471	1,503	1,081	1,047	1,218	1,272	1,252	**2,751**
1986	1,757	2,510	2,328	3,782	4,441	5,776	3,230	704	876	1,373	2,034	1,606	**2,535**
1987	1,294	2,641	3,127	5,225	7,285	4,219	1,500	1,379	1,532	1,554	1,399	763	**2,660**
1988	701	772	1,470	1,910	1,725	1,103	749	854	808	522	811	752	**1,015**
1989	731	810	2,026	3,397	1,653	844	1,023	807	586	558	476	575	**1,124**
1990	550	619	878	1,062	1,693	1,056	1,093	919	1,065	769	1,103	851	**972**
1991	848	1,063	1,524	3,055	4,562	3,460	1,390	1,523	1,115	692	1,215	1,129	**1,798**
1992	862	1,033	1,784	3,968	3,734	2,899	1,240	1,076	1,161	860	624	708	**1,662**
1993	900	1,140	1,559	3,101	5,518	4,806	1,629	1,213	1,328	836	1,259	1,243	**2,044**
1994	878	869	1,603	3,476	5,881	4,026	1,037	818	866	853	737	945	**1,833**
1995	974	1,243	1,945	2,301	4,682	6,484	4,548	1,009	1,046	1,127	1,258	1,034	**2,304**
1996	1,176	1,300	1,305	872	1,169	1,122	806	847	758	603	538	611	**926**
1997	707	857	1,474	1,569	4,274	4,389	1,340	1,209	1,467	2,225	1,382	1,012	**1,825**
1998	949	967	1,349	1,702	3,570	1,840	1,336	1,203	1,284	966	780	746	**1,391**
1999	798	779	765	1,015	3,603	3,086	1,514	2,132	1,553	1,040	804	725	**1,485**

1971-1999 Summary

Minimum	436	500	612	489	433	470	394	391	263	361	401	450	**599**
Maximum	1,757	2,641	3,127	6,412	8,390	7,914	4,548	2,132	1,553	2,225	2,034	1,959	**2,751**
Mean	824	948	1,403	2,299	3,778	3,354	1,597	1,002	906	841	983	951	**1,574**
Median	731	857	1,349	2,078	3,734	3,460	1,336	952	876	819	1,009	851	**1,662**
Std. Dev.	291	495	570	1433	2231	2165	1021	357	372	391	402	385	**649**

TABLE C-1. (CONT.) MONTHLY RIO GRANDE FLOWS AT OTOWI, 1971-1999

Append B All Gages\Otowi cont

Year	January Average (cfs)	February Average (cfs)	March Averge (cfs)	April Average (cfs)	May Average (cfs)	June Average (cfs)	July Average (cfs)	August Average (cfs)	September Average (cfs)	October Average (cfs)	November Average (cfs)	December Average (cfs)	**Annual Average (cfs)**
1943	801	856	841	1,785	1,618	1,554	1,140	1,124	908	578	576	639	**1,035**
1944	632	804	989	1,179	6,704	5,238	1,974	1,391	1,029	809	722	775	**1,854**
1945	782	978	900	1,567	7,261	2,796	1,237	1,132	974	702	665	604	**1,633**
1946	617	636	653	746	748	967	500	567	331	382	1,313	1,488	**746**
1947	602	714	649	796	2,493	1,090	941	960	467	637	1,861	1,282	**1,041**
1948	629	818	1,117	2,778	4,851	6,223	827	755	480	395	523	622	**1,668**
1949	638	1,354	2,124	1,617	3,619	6,122	2,797	807	706	579	659	663	**1,807**
1950	715	2,241	1,680	1,126	580	917	763	611	363	331	360	490	**865**
1951	511	1,042	439	348	741	745	432	465	168	188	339	486	**492**
1952	792	623	943	2,682	6,087	5,656	2,293	1,746	448	370	488	672	**1,900**
1953	696	870	905	927	987	1,810	481	417	141	240	472	539	**707**
1954	523	692	561	835	1,455	569	537	290	386	311	318	388	**572**
1955	469	498	507	336	1,386	745	603	1,011	926	251	363	480	**623**
1956	664	560	666	929	877	677	344	252	197	123	279	351	**476**
1957	400	531	469	1,068	3,380	4,983	4,300	3,465	1,760	1,124	1,726	932	**2,008**
1958	735	960	1,100	3,980	8,349	3,980	429	823	673	367	1,634	1,329	**2,030**
1959	682	622	601	588	877	370	316	596	247	491	765	595	**554**
1960	586	629	1,489	3,108	2,115	2,335	483	369	354	381	647	542	**1,087**
1961	509	614	693	1,383	3,089	1,209	514	878	636	498	1,688	1,133	**1,070**
1962	660	1,185	1,046	4,020	3,741	1,422	550	368	416	366	1,499	1,491	**1,397**
1963	693	803	1,072	1,586	516	255	163	290	299	190	553	358	**565**
1964	441	484	520	625	1,373	451	264	458	311	190	658	419	**516**
1965	701	695	764	2,117	4,013	4,405	3,021	1,175	755	963	1,715	1,886	**1,851**
1966	915	877	1,665	2,317	2,468	1,203	331	786	216	268	1,233	792	**1,089**
1967	580	729	768	493	989	1,137	420	1,878	762	313	1,096	595	**813**
1968	664	737	957	1,035	2,704	3,251	773	2,344	394	319	1,259	652	**1,257**
1969	820	766	913	2,473	3,989	3,603	1,006	1,045	1,066	1,430	1,751	1,350	**1,683**
1970	868	1,031	1,081	1,153	2,651	2,069	741	500	1,114	823	1,530	901	**1,205**
1971	776	961	1,120	1,243	840	434	715	507	303	910	1,278	790	**823**
1972	745	931	1,214	564	366	411	403	428	534	652	1,039	757	**670**
1973	706	722	1,110	1,824	5,671	5,111	3,374	1,646	1,042	790	856	1,682	**2,036**
1974	1,443	811	1,134	911	936	906	565	708	206	289	461	505	**740**
1975	511	652	963	1,819	3,597	3,397	2,771	831	904	552	1,465	1,749	**1,601**
1976	1,197	727	818	1,195	2,336	1,277	1,081	1,006	629	398	440	506	**984**
1977	462	552	546	378	521	945	767	668	377	421	466	600	**550**
1978	531	600	747	764	2,563	2,245	907	596	436	338	725	694	**929**
1979	583	679	1,435	3,527	5,578	6,150	5,979	1,160	665	703	1,658	1,545	**2,472**
1980	701	960	1,009	2,178	6,061	6,101	1,872	704	485	422	1,310	1,445	**1,937**
1981	760	591	589	548	689	776	622	635	369	495	772	608	**620**
1982	573	658	951	1,885	4,010	3,950	1,404	1,228	1,651	1,035	1,044	896	**1,607**
1983	779	990	1,541	2,312	5,010	6,534	3,415	892	641	488	577	1,068	**2,021**
1984	812	771	1,317	2,998	5,982	5,129	956	961	675	703	990	1,013	**1,859**
1985	919	1,064	2,190	6,126	6,160	4,683	3,245	890	673	984	607	797	**2,395**
1986	2,163	3,695	3,054	2,854	2,775	3,984	3,332	3,667	1,781	1,370	2,072	1,969	**2,726**
1987	1,414	2,817	2,560	2,756	4,397	3,839	4,792	1,244	700	676	1,057	1,113	**2,280**
1988	1,199	1,671	2,157	2,535	2,103	1,146	758	749	979	581	945	797	**1,302**
1989	761	838	1,841	3,641	1,644	746	1,017	822	962	472	389	764	**1,125**
1990	602	694	835	927	1,406	902	830	742	967	761	1,036	834	**878**
1991	876	1,016	1,319	2,517	3,446	4,056	1,609	1,573	1,111	664	1,152	1,188	**1,702**
1992	887	729	1,343	4,380	4,200	2,943	1,237	956	926	744	619	726	**1,641**
1993	954	1,024	1,539	3,089	4,914	4,799	1,617	1,334	1,286	705	1,148	1,213	**1,968**
1994	902	900	1,578	3,425	4,852	5,342	1,021	830	791	781	774	959	**1,846**
1995	1,038	1,167	1,729	2,163	4,799	5,698	5,621	1,078	993	1,038	1,183	1,001	**2,292**
1996	1,153	1,255	1,214	792	986	1,004	942	898	692	661	579	636	**901**
1997	717	871	1,313	1,437	3,937	5,079	1,182	1,149	1,352	1,430	1,751	1,350	**1,797**
1998	868	1,031	1,081	1,153	2,651	2,069	741	500	1,114	823	1,530	901	**1,205**

1943-1998 Summary

Minimum	400	484	439	336	366	255	163	252	141	123	279	351	**476**
Maximum	2,163	3,695	3,054	6,126	8,349	6,534	5,979	3,667	1,781	1,430	2,072	1,969	**2,726**
Mean	771	942	1,153	1,849	3,073	2,777	1,442	980	710	598	975	899	**1,347**
Median	711	808	1,069	1,576	2,677	2,157	924	831	674	565	900	791	**1,231**
Std. Dev.	292	543	545	1,213	2,028	2,026	1,373	663	395	312	485	405	**608**

1943-1970 Summary

Minimum	400	484	439	336	515	255	163	252	141	123	279	351	**476**
Maximum	915	2,241	2,124	4,020	8,349	6,223	4,300	3,465	1,760	1,430	1,861	1,886	**2,030**
Mean	647	834	939	1,557	2,846	2,345	1,003	947	590	486	953	802	**1,162**
Median	635	751	903	1,166	2,461	1,486	543	796	457	375	694	646	**1,079**
Std. Dev.	128	344	417	1025	2162	1921	988	709	374	309	541	407	**528**

1971-1998 Summary

Minimum	462	552	546	378	366	411	403	428	206	289	389	500	**550**
Maximum	2,163	3,695	3,054	6,126	6,160	6,634	5,979	3,667	1,781	1,430	2,072	1,969	**2,726**
Mean	894	1,049	1,366	2,141	3,301	3,209	1,881	1,014	830	710	997	997	**1,532**
Median	795	886	1,263	2,024	3,522	3,618	1,131	891	810	690	1,013	898	**1,624**
Std. Dev.	355	677	579	1331	1896	2070	1570	602	385	278	431	387	**634**

TABLE C-2. MONTHLY RIO GRANDE FLOWS AT SAN FELIPE, 1943-1998

Append B All Gages \ Table C-2 San Felipe

Year	January Average (cfs)	February Average (cfs)	March Averge (cfs)	April Average (cfs)	May Average (cfs)	June Average (cfs)	July Average (cfs)	August Average (cfs)	September Average (cfs)	October Average (cfs)	November Average (cfs)	December Average (cfs)	**Annual Average (cfs)**
1943	801	856	841	1,785	1,618	1,554	1,140	1,124	908	578	576	639	**1,035**
1944	701	810	845	1,013	6,551	4,962	1,573	1,076	565	592	515	753	**1,663**
1945	784	934	766	1,760	7,302	2,372	738	607	446	436	412	571	**1,427**
1946	595	648	431	334	273	337	205	355	107	205	1,255	1,557	**525**
1947	601	688	369	463	2,079	608	510	599	157	344	1,736	1,284	**786**
1948	594	872	969	2,813	4,785	6,114	368	348	168	123	529	635	**1,526**
1949	640	1,337	2,103	1,763	3,556	5,909	2,468	476	455	277	625	684	**1,693**
1950	671	2,146	1,551	770	226	413	414	308	163	89	305	489	**627**
1951	515	1,073	167	109	393	342	177	375	40	32	229	458	**326**
1952	800	607	776	2,621	6,229	5,538	2,019	1,484	157	108	399	667	**1,784**
1953	698	859	745	613	575	1,266	161	151	16	25	315	503	**494**
1954	494	638	347	525	1,065	219	229	127	151	83	179	334	**365**
1955	443	473	264	65	1,002	314	289	797	533	49	266	495	**414**
1956	580	564	477	632	537	229	96	82	21	0	68	270	**296**
1957	406	529	281	773	3,171	4,803	4,183	3,687	1,615	1,260	2,211	964	**1,990**
1958	728	1,071	1,116	4,166	8,831	4,832	224	459	401	120	1,542	1,356	**2,071**
1959	594	661	385	301	563	109	88	358	45	152	665	525	**371**
1960	539	620	1,385	3,249	1,795	1,969	108	84	83	249	600	538	**935**
1961	459	583	517	1,466	2,910	909	113	588	316	231	1,934	1,214	**937**
1962	703	1,307	900	3,934	3,775	1,034	263	28	48	116	1,420	1,552	**1,257**
1963	683	843	953	1,433	112	12	0	32	40	2	493	305	**409**
1964	392	453	279	351	941	189	1	70	16	1	444	376	**293**
1965	621	680	590	1,957	4,122	4,371	2,759	1,021	443	695	1,810	2,054	**1,758**
1966	1,016	898	1,569	2,112	2,104	768	86	333	13	7	1,143	765	**901**
1967	613	690	504	162	435	749	164	1,694	395	17	1,065	688	**595**
1968	891	737	842	995	2,502	2,589	283	2,029	164	1	1,173	596	**1,050**
1969	870	790	750	2,350	3,689	3,381	531	620	843	1,404	1,829	1,397	**1,538**
1970	810	1,084	777	876	2,604	1,811	322	218	696	507	1,602	915	**1,018**
1971	673	1,036	1,082	1,089	627	125	348	286	38	746	1,296	828	**681**
1972	713	810	1,161	378	28	4	26	71	280	442	1,116	705	**478**
1973	684	726	1,126	2,034	6,290	5,284	3,015	1,334	717	446	849	1,681	**2,016**
1974	1,487	786	873	583	683	550	287	399	51	156	428	480	**564**
1975	491	663	866	2,027	3,957	3,308	2,424	584	817	290	1,483	1,736	**1,554**
1976	1,254	751	768	974	2,274	784	704	701	559	53	482	571	**823**
1977	486	596	480	137	148	454	377	430	70	38	401	513	**344**
1978	534	590	612	487	2,704	2,039	531	278	75	63	763	767	**787**
1979	702	807	1,716	3,596	5,861	6,069	6,439	980	291	256	1,723	1,568	**2,417**
1980	817	1,031	948	2,273	6,203	6,042	1,676	481	353	154	1,394	1,551	**1,910**
1981	857	609	509	368	455	445	333	343	127	245	754	704	**479**
1982	648	774	804	2,086	3,787	3,625	919	1,001	1,495	666	1,060	997	**1,488**
1983	811	959	1,566	2,352	5,035	6,113	2,767	464	239	256	625	957	**1,845**
1984	832	766	1,250	2,716	5,814	4,437	669	651	332	506	985	1,077	**1,669**
1985	985	1,006	2,287	6,343	6,005	4,454	2,746	526	620	961	610	682	**2,267**
1986	2,159	3,562	2,790	2,449	2,419	3,434	2,923	3,452	1,554	1,291	2,302	2,276	**2,551**
1987	1,428	3,024	2,517	2,391	4,247	3,905	4,966	1,129	383	443	1,092	1,131	**2,221**
1988	1,199	1,662	1,977	2,625	2,055	859	592	514	1,096	408	904	741	**1,219**
1989	846	812	1,819	3,326	1,204	336	519	497	245	320	145	845	**910**
1990	639	663	665	686	1,229	432	678	425	585	552	956	825	**695**
1991	852	928	1,166	2,532	3,139	3,616	1,334	1,671	1,155	400	1,302	1,262	**1,605**
1992	926	753	1,215	3,969	4,313	2,690	607	737	578	476	673	777	**1,475**
1993	1,179	1,039	1,565	3,569	5,010	5,280	1,407	844	924	492	1,272	1,292	**1,989**
1994	894	857	1,355	3,096	4,675	4,687	772	696	515	548	1,027	1,072	**1,683**
1995	1,081	1,160	2,130	2,205	4,849	5,411	4,831	748	649	695	1,258	1,088	**2,176**
1996	1,259	1,499	1,110	470	671	722	529	629	419	388	597	674	**731**
1997	799	917	1,296	1,402	3,685	4,243	1,049	1,026	1,128	1,802	1,378	1,096	**1,652**
1998	1,011	1,034	1,288	1,471	3,177	1,366	858	732	700	681	1,016	841	**1,181**

1943-1998 Summary

Minimum	392	453	167	55	28	4	0	28	13	0	68	270	**293**
Maximum	2,159	3,562	2,790	6,343	8,831	6,114	5,439	3,687	1,615	1,802	2,302	2,276	**2,551**
Mean	791	951	1,044	1,732	2,932	2,472	1,122	724	446	384	950	916	**1,205**
Median	703	810	886	1,616	2,654	1,890	531	527	368	283	930	772	**1,116**
Std. Dev.	308	546	597	1,305	2,207	2,113	1,360	702	409	381	547	447	**647**

1943-1970 Summary

Minimum	392	453	167	55	112	12	0	28	13	0	66	270	**293**
Maximum	1,016	2,146	2,103	4,166	8,831	6,114	4,183	3,687	1,615	1,404	2,211	2,054	**2,071**
Mean	645	837	768	1,406	2,634	2,061	697	683	322	275	905	805	**1,003**
Median	630	764	758	1,004	2,091	1,150	273	417	163	122	612	663	**936**
Std. Dev.	144	343	455	1152	2355	2048	1010	783	362	360	635	451	**572**

1971-1998 Summary

Minimum	486	590	480	137	28	4	26	71	38	38	145	480	**344**
Maximum	2,159	3,562	2,790	6,343	6,290	6,113	6,439	3,452	1,554	1,802	2,302	2,276	**2,551**
Mean	937	1,065	1,319	2,068	3,230	2,883	1,547	765	571	492	996	1,026	**1,407**
Median	849	834	1,191	2,146	3,431	3,371	815	617	537	442	1,000	901	**1,521**
Std. Dev.	358	679	601	1387	2046	2134	1522	623	420	377	451	422	**663**

TABLE C-3. MONTHLY RIO GRANDE FLOWS AT ALBUQUERQUE, 1943-1998

Append B All Gages\Table C-3 Abq

Year	January Average (cfs)	February Average (cfs)	March Averge (cfs)	April Average (cfs)	May Average (cfs)	June Average (cfs)	July Average (cfs)	August Average (cfs)	September Average (cfs)	October Average (cfs)	November Average (cfs)	December Average (cfs)	**Annual Average (cfs)**
1943										411	398	729	**513**
1944	663	814	851	869	6,399	4,963	1,457	748	452	761	592	838	**1,618**
1945	806	911	707	1,432	6,734	1,932	503	500	333	521	431	700	**1,292**
1946	680	673	524	165	151	51	53	110	101	148	1,186	1,682	**460**
1947	643	676	313	267	1,623	278	261	496	123	198	1,783	1,296	**679**
1948	659	953	1,017	2,514	4,267	5,941	229	114	63	84	566	694	**1,425**
1949	680	1,216	1,907	1,381	3,285	5,356	2,338	433	273	227	719	762	**1,548**
1950	738	1,962	1,343	623	100	119	287	128	81	27	180	462	**506**
1951	551	1,033	150	60	98	123	39	146	21	2	30	350	**216**
1952	796	628	697	2,270	5,587	5,062	1,606	1,200	130	61	366	719	**1,593**
1953	729	863	771	427	348	1,066	84	29	2				**480**
1954										107	112	338	**185**
1955	471	498	226	55	601	226	101	582	320	96	192	525	**324**
1956	626	605	362	398	329	80	14	10		1	11	150	**235**
1957	367	504	231	466	2,563	3,829	4,024	3,236	1,516	1,076	1,972	1,023	**1,733**
1958	778	945	1,065	3,846	7,860	4,435	185	173	278	138	1,416	1,305	**1,869**
1959	602	606	390	129	309	46	1	149	12	76	660	626	**300**
1960	605	657	1,183	2,635	1,413	1,646	68	5	1	176	566	548	**809**
1961	516	599	453	1,029	2,436	601	70	274	219	149	1,493	1,203	**754**
1962	731	1,218	790	3,345	3,245	562	112	2	21	110	1,167	1,452	**1,063**
1963	694	850	649	924	51	1	1	1	1	1	234	293	**308**
1964	377	446	165	70	445	176	1	1	1	1	268	368	**193**
1965	646	639	382	1,492	3,350	3,574	2,163	830	270	527	1,686	1,936	**1,459**
1966	951	856	1,347	1,675	1,601	461	71	90	1	1	627	696	**715**
1967	554	659	295	7	66	464	2	1,338	275	26	830	649	**430**
1968	636	733	773	862	1,957	1,841	166	1,756	34	1	998	627	**849**
1969	821	794	514	1,913	3,311	2,668	157	288	617	1,003	1,706	1,344	**1,261**
1970	867	1,007	669	522	2,191	1,602	72	41	210	371	1,516	919	**832**
1971	797	944	715	770	222	2	51	64	14	315	1,217	863	**498**
1972	814	862	831	128	4	1	1	5	233	392	1,180	801	**438**
1973	740	754	1,016	1,667	5,914	5,142	2,656	934	614	322	877	1,696	**1,861**
1974	1,454	873	699	360	178	26	49	36	42	169	469	508	**403**
1975	474	721	723	1,374	3,782	2,940	2,269	207	832	130	1,452	1,771	**1,390**
1976	1,270	639	473	458	1,854	296	136	408	216	106	484	547	**574**
1977	472	366	186	65	1	1	13	132	3	1	311	463	**169**
1978	477	524	372	65	2,572	1,397	171	3	12	10	728	776	**592**
1979	667	743	1,286	3,030	5,606	6,196	5,277	777	289	188	1,693	1,470	**2,268**
1980	859	1,032	884	1,884	6,766	5,334	1,343	337	289	16	1,269	1,551	**1,713**
1981	979	626	413	44	77	1	13	12	50	89	763	632	**308**
1982	596	609	557	1,582	3,661	3,130	599	612	1,182	827	1,119	924	**1,283**
1983	862	1,060	1,348	1,719	4,791	5,508	2,116	341	43	185	668	1,056	**1,642**
1984	745	773	1,043	2,465	5,485	4,557	639	436	53	597	1,081	1,077	**1,579**
1985	928	861	1,920	5,169	5,424	3,506	2,489	337	565	1,025	706	715	**1,971**
1986	2,271	3,712	2,768	2,166	2,131	3,179	2,619	2,926	1,416	1,626	2,142	2,097	**2,420**
1987	1,473	3,111	2,395	2,106	4,038	3,472	4,597	1,175	182	290	1,121	1,222	**2,097**
1988	1,170	1,758	2,276	2,164	1,764	593	382	349	1,135	231	846	842	**1,126**
1989	792	1,003	1,809	3,191	1,012	1	156	153	4	91	178	749	**762**
1990	692	726	467	578	673	152	273	230	136	376	1,116	895	**543**
1991	935	957	1,070	1,959	2,882	3,571	1,296	1,279	733	208	1,507	1,518	**1,493**
1992	1,109	945	1,696	3,440	3,946	2,643	380	647	410	357	633	884	**1,432**
1993	1,297	1,299	1,730	3,063	4,255	4,594	980	585	842	340	1,340	1,469	**1,815**
1994	1,130	1,043	1,358	2,880	5,182	4,554	540	556	359	402	1,107	1,025	**1,678**
1995	1,053	1,220	1,823	1,965	4,301	4,632	4,459	635	663	565	1,492	1,232	**1,985**
1996	1,181	1,218	857	143	61	256	326	149	206	178	727	739	**503**
1997	860	999	997	1,313	3,486	4,691	694	962	918	1,871	1,670	1,319	**1,648**
1998	1,062	1,100	1,208	1,222	2,874	981	663	377	275	465	1,045	822	**1,009**

1943-1998 Summary

Minimum	367	366	150	7	1	1	1	1	1	1	11	150	**169**
Maximum	2,271	3,712	2,768	5,169	7,860	6,196	5,277	3,236	1,516	1,871	2,142	2,097	**2,420**
Mean	822	960	939	1,412	2,642	2,194	912	503	320	321	927	944	**1051**
Median	743	859	782	1,344	2,500	1,624	267	337	216	185	846	838	**929**
Std. Dev.	324	569	610	1,198	2,161	2,080	1,320	650	376	389	536	443	**637**

1943-1970 Summary

Minimum	367	446	150	7	51	1	1	1	1	1	11	150	**185**
Maximum	951	1,962	1,907	3,846	7,860	5,941	4,024	3,236	1,516	1,076	1,972	1,936	**1,869**
Mean	661	821	684	1,128	2,328	1,812	542	488	214	233	811	824	**845**
Median	661	763	659	760	1,890	833	107	161	123	110	660	700	**734**
Std. Dev.	138	310	428	1085	2281	1981	962	725	316	302	600	446	**539**

1971-1998 Summary

Minimum	472	366	186	44	1	1	1	3	3	1	178	463	**169**
Maximum	2,271	3,712	2,768	5,169	5,914	6,196	5,277	2,926	1,416	1,871	2,142	2,097	**2,420**
Mean	971	1,089	1,176	1,676	2,934	2,548	1,257	617	414	405	1,040	1,060	**1257**
Median	905	945	1,029	1,693	3,184	3,036	619	363	282	302	1,094	910	**1,411**
Std. Dev.	375	715	663	1256	2041	2142	1507	595	405	448	447	416	**668**

TABLE C-4. MONTHLY RIO GRANDE FLOWS AT BERNARDO, 1943-1998

Append B All Gages \ Table C-4 Bernardo

Year	January Average (cfs)	February Average (cfs)	March Averge (cfs)	April Average (cfs)	May Average (cfs)	June Average (cfs)	July Average (cfs)	August Average (cfs)	September Average (cfs)	October Average (cfs)	November Average (cfs)	December Average (cfs)	**Annual Average (cfs)**
1943	839	753	505	844	678	520	491	555	279	288	325	733	**584**
1944	729	795	777	763	6,752	4,327	1,602	860	321	799	534	806	**1,504**
1945	774	909	655	1,293	6,460	1,833	362	487	223	451	381	761	**1,216**
1946	741	644	454	60	69	7	31	411	130	184	1,078	1,562	**448**
1947	676	639	260	115	1,723	193	188	1,247	162	177	1,660	1,257	**691**
1948	704	937	992	2,327	4,021	5,778	139	69	64	35	600	699	**1,365**
1949	676	1,235	1,874	1,330	3,175	5,038	2,560	423	289	212	707	765	**1,524**
1950	739	1,971	1,281	504	43	40	266	122	178	13	163	518	**487**
1951	557	1,088	112	5	30	47	3	510	10	0	4	319	**222**
1952	779	621	642	2,104	5,234	4,883	1,610	1,190	85	11	301	683	**1,512**
1953	718	863	725	296	249	934	383	324	2	1	42	468	**419**
1954	532	626	240	278	680	30	324	471	657	284	104	355	**382**
1955	493	514	188	12	524	174	480	1,544	299	83	165	538	**418**
1956	636	634	328	319	256	18	6	182	0	0	9	158	**212**
1957	372	509	227	375	2,260	3,692	4,084	4,055	1,541	1,416	2,046	1,029	**1,800**
1958	816	1,043	1,069	3,347	7,256	4,222	126	121	299	153	1,420	1,336	**1,767**
1959	663	665	336	74	279	17	7	402	2	17	692	633	**316**
1960	632	675	1,349	2,647	1,342	1,556	19	5	30	291	564	587	**808**
1961	564	649	373	911	2,329	503	43	402	344	85	1,535	1,234	**748**
1962	757	1,286	715	3,141	3,097	449	74	10	140	133	1,196	1,508	**1,042**
1963	755	903	658	921	57	2	1	219	199	9	229	296	**354**
1964	397	494	162	73	398	172	94	190	49	1	270	411	**226**
1965	700	719	375	1,346	3,252	3,437	2,114	1,229	637	466	1,692	1,909	**1,481**
1966	965	891	1,256	1,530	1,418	468	159	302	72	6	837	766	**722**
1967	585	699	248	11	58	552	148	2,390	684	90	902	704	**586**
1968	701	784	672	567	1,759	1,866	223	2,598	160	38	995	673	**920**
1969	865	852	558	1,872	3,150	2,794	252	465	789	1,514	1,780	1,450	**1,362**
1970	930	1,066	644	427	1,810	1,283	152	227	236	359	1,495	972	**800**
1971	816	959	602	863	130	3	57	218	60	540	1,228	914	**516**
1972	850	931	787	81	3	20	91	602	903	1,053	1,208	825	**613**
1973	818	854	1,147	1,669	6,004	4,769	2,704	942	592	313	966	1,745	**1,876**
1974	1,523	922	650	299	116	8	59	196	162	346	569	636	**457**
1975	586	814	799	1,297	3,593	2,908	2,211	336	1,459	203	1,482	1,802	**1,457**
1976	1,308	829	385	422	1,898	324	210	469	246	140	567	629	**619**
1977	567	646	246	82	29	16	108	656	160	45	380	558	**291**
1978	566	590	444	72	2,167	1,234	245	12	14	34	782	801	**580**
1979	760	1,012	1,214	2,866	5,664	5,628	4,580	834	282	155	1,708	1,601	**2,192**
1980	861	1,030	792	1,873	6,075	5,288	1,161	325	669	38	1,208	1,481	**1,725**
1981	930	657	433	57	109	16	163	134	254	287	847	777	**389**
1982	742	791	714	1,049	3,450	2,720	904	1,033	2,100	781	1,374	1,093	**1,396**
1983	973	1,256	1,657	2,193	4,744	5,456	2,446	427	190	370	677	1,130	**1,785**
1984	854	846	1,046	2,258	5,070	4,317	608	570	111	783	1,207	1,219	**1,574**
1985	1,098	1,130	2,473	5,761	6,086	3,859	2,512	903	1,055	1,301	919	971	**2,306**
1986	2,626	3,849	3,106	2,390	2,609	3,459	3,732	3,462	1,945	1,892	2,645	2,209	**2,827**
1987	1,329	3,104	2,786	2,392	3,919	3,479	4,312	1,211	90	223	1,220	1,382	**2,121**
1988	1,131	1,752	1,757	2,429	1,673	506	451	1,061	1,908	409	914	1,050	**1,254**
1989	1,054	1,036	1,639	2,960	1,221	9	269	298	50	151	468	867	**834**
1990	829	782	520	529	844	98	395	362	357	540	1,308	1,082	**637**
1991	1,103	1,168	1,052	1,922	2,675	3,546	1,593	1,585	948	234	1,946	1,673	**1,620**
1992	956	1,019	1,377	3,399	4,332	2,314	356	487	339	332	817	931	**1,388**
1993	1,138	1,120	1,594	2,995	4,315	4,568	982	1,143	1,066	267	1,601	1,556	**1,862**
1994	1,099	972	1,233	2,661	4,510	4,146	377	626	544	474	1,267	1,112	**1,585**
1995	1,193	1,340	1,900	1,776	4,229	4,620	4,197	526	655	537	1,061	917	**1,904**
1996	1,216	1,450	866	97	108	317	159	297	380	293	945	905	**586**
1997	846	957	999	1,387	3,311	3,948	633	1,026	1,119	1,776	1,791	1,308	**1,592**
1998	1,151	1,157	1,203	1,161	2,766	851	880	431	195	500	1,200	846	**1,028**

1943-1998 Summary

Minimum	372	494	112	5	3	2	1	5	0	0	4	158	**212**
Maximum	2,626	3,849	3,106	5,761	7,256	5,778	4,580	4,055	2,100	1,892	2,645	2,209	**2,827**
Mean	861	1,007	911	1,325	2,486	2,022	935	729	454	377	965	985	**1,088**
Median	797	897	720	1,100	2,214	1,259	340	470	267	251	932	910	**974**
Std. Dev.	339	563	648	1,206	2,101	1,969	1,271	794	517	450	585	446	**640**

1943-1970 Summary

Minimum	372	494	112	5	30	2	1	5	0	0	4	158	**212**
Maximum	966	1,971	1,874	3,347	7,256	5,778	4,084	4,055	1,641	1,514	2,046	1,909	**1,800**
Mean	689	837	631	981	2,058	1,601	569	751	278	253	776	827	**854**
Median	702	768	600	660	1,570	536	174	417	188	109	646	719	**735**
Std. Dev.	141	304	425	985	2094	1863	962	924	326	390	618	436	**508**

1971-1998 Summary

Minimum	566	590	246	57	3	3	57	12	14	34	380	558	**291**
Maximum	2,626	3,849	3,106	5,761	6,086	5,628	4,580	3,462	2,100	1,892	2,645	2,209	**2,827**
Mean	1,033	1,178	1,190	1,869	2,916	2,444	1,300	706	630	501	1,163	1,144	**1,322**
Median	964	992	1,049	1,722	3,039	2,814	620	514	369	339	1,204	1,066	**1,427**
Std. Dev.	391	703	717	1322	2054	2055	1445	656	611	478	491	405	**680**

TABLE C-5. MONTHLY RIO GRANDE FLOWS AT SAN ACACIA, 1943-1998

Append B All Gages\Table C-5 San Acacia

Year	January Average (cfs)	February Average (cfs)	March Averge (cfs)	April Average (cfs)	May Average (cfs)	June Average (cfs)	July Average (cfs)	August Average (cfs)	September Average (cfs)	October Average (cfs)	November Average (cfs)	December Average (cfs)	**Annual Average (cfs)**
1943	858	788	601	801	883	355	583	470	274	277	325	720	**578**
1944	669	713	731	731	5,274	4,366	1,440	726	235	765	514	726	**1,407**
1945	774	857	668	1,172	6,188	1,636	260	358	124	389	356	652	**1,119**
1946	672	613	521	66	83	1	8	259	115	166	790	1,503	**400**
1947	593	596	327	83	1,540	135	74	939	168	106	1,394	1,213	**597**
1948	601	889	923	2,232	3,573	6,070	132	70	24	35	387	584	**1,293**
1949	632	1,144	1,814	1,216	3,117	4,862	2,604	438	266	181	582	620	**1,457**
1950	681	1,861	1,301	492	75	11	81	136	94	42	65	331	**431**
1951	411	861	169	46	49	27	2	217	31	0	0	129	**162**
1952	535	456	501	1,785	5,120	4,898	1,488	1,011	94	26	84	616	**1,381**
1953	634	772	741	210	333	783	293	262	22	8	27	260	**362**
1954	412	559	245	238	687	65	132	366	426	254	71	251	**299**
1955	443	477	247	66	346	191	279	1,386	248	143	125	413	**364**
1956	555	578	348	326	266	40	6	92	5	5	7	39	**189**
1957	224	376	254	305	2,052	3,477	3,803	3,795	1,689	1,497	1,957	1,011	**1,703**
1958	826	994	1,175	3,295	7,166	4,395	288	126	308	221	1,274	1,338	**1,784**
1959	619	592	434	242	344	121	50	399	37	53	615	608	**343**
1960	613	613	1,205	2,547	1,395	1,608	169	25	14	248	524	308	**763**
1961	436	561	539	894	2,205	655	140	368	373	158	1,437	1,250	**752**
1962	780	1,248	770	2,721	3,099	598	208	66	108	183	1,144	1,474	**1,033**
1963	783	907	717	1,018	176	19	2	132	205	13	214	291	**373**
1964	375	467	255	129	397	212	122	201	45	6	237	354	**233**
1965	651	639	412	1,096	2,960	3,278	2,124	1,221	615	591	1,641	1,900	**1,427**
1966	1,071	941	1,395	1,884	1,539	561	251	321	122	39	778	743	**787**
1967	565	687	361	77	74	517	207	1,661	797	159	854	733	**558**
1968	729	796	798	646	1,673	1,831	347	1,977	143	76	970	702	**891**
1969	859	875	648	1,685	3,014	2,627	385	462	787	1,284	1,830	1,586	**1,337**
1970	996	1,079	804	576	1,724	1,380	262	331	243	369	1,466	1,020	**854**
1971	841	1,002	712	778	302	24	45	268	66	486	1,198	914	**553**
1972	882	848	862	209	37	34	124	533	943	945	1,291	886	**634**
1973	806	853	1,140	1,862	5,249	4,492	2,623	1,065	726	427	931	1,658	**1,794**
1974	1,558	1,021	762	452	223	54	77	188	139	338	527	546	**490**
1975	507	774	820	1,184	3,355	2,651	2,163	317	1,322	163	1,423	1,804	**1,374**
1976	1,353	732	499	490	1,674	403	285	469	294	223	526	619	**630**
1977	556	626	378	183	55	1	94	613	171	93	377	586	**311**
1978	581	639	508	146	1,839	1,310	287	10	7	31	748	819	**577**
1979	758	934	1,351	2,672	4,998	5,358	4,672	993	364	299	1,604	1,795	**2,141**
1980	1,015	1,168	865	1,519	5,370	5,143	1,266	483	653	148	1,107	1,412	**1,679**
1981	925	748	551	107	100	15	135	106	326	194	632	540	**365**
1982	572	641	633	1,496	3,414	2,801	716	689	1,342	692	1,212	1,053	**1,272**
1983	937	1,099	1,470	1,611	4,492	5,332	2,290	495	209	260	582	1,084	**1,655**
1984	962	907	1,035	2,279	4,591	4,218	775	455	251	759	1,159	1,231	**1,552**
1985	1,155	1,126	2,132	5,178	5,739	3,666	2,316	538	520	1,203	803	744	**2,093**
1986	2,261	3,345	2,849	2,183	2,262	3,089	3,177	2,777	1,506	1,814	2,377	2,056	**2,474**
1987	1,291	2,913	2,399	2,362	4,034	3,505	4,258	1,479	233	298	1,015	1,167	**2,081**
1988	1,291	1,593	1,824	2,470	1,526	682	394	1,417	1,713	397	1,007	974	**1,274**
1989	913	1,056	1,379	3,024	1,445	125	284	347	162	175	278	492	**807**
1990	727	633	542	573	822	239	444	408	423	479	1,138	910	**611**
1991	891	1,033	1,031	1,755	2,998	3,230	1,836	1,219	770	381	1,739	1,550	**1,536**
1992	860	890	1,279	3,617	4,686	2,612	611	719	467	409	914	902	**1,489**
1993	1,107	1,190	1,759	3,079	3,788	4,625	1,148	991	913	502	1,333	1,451	**1,824**
1994	950	961	1,249	2,513	4,223	4,124	681	829	675	571	1,152	1,079	**1,584**
1995	1,080	1,251	1,784	1,803	4,076	4,419	4,279	793	630	600	1,280	1,160	**1,930**
1996	1,254	1,301	895	287	141	259	582	381	570	408	704	656	**620**
1997	794	1,113	991	1,338	2,989	3,685	849	1,208	926	1,914	1,804	1,361	**1,581**
1998	1,140	1,096	1,221	1,150	2,753	1,213	754	498	295	604	1,133	885	**1,062**

1943-1998 Summary

Minimum	224	376	169	46	37	1	2	10	5	0	0	39	**162**
Maximum	2,261	3,345	2,849	5,178	7,166	6,070	4,672	3,795	1,713	1,914	2,377	2,056	**2,474**
Mean	821	954	926	1,293	2,365	1,999	941	680	433	395	887	924	**1,051**
Median	781	868	784	1,123	1,946	1,345	320	460	270	257	884	885	**962**
Std. Dev.	335	509	570	1,119	1,960	1,934	1,222	684	432	433	565	480	**606**

1943-1970 Summary

Minimum	224	376	169	46	49	1	2	25	5	0	0	39	**162**
Maximum	1,071	1,861	1,814	3,295	7,166	6,070	3,803	3,795	1,689	1,497	1,957	1,900	**1,784**
Mean	643	784	675	942	1,973	1,593	561	636	272	260	702	763	**817**
Median	633	743	625	690	1,640	627	230	367	165	158	553	677	**757**
Std. Dev.	169	303	402	906	1999	1865	911	800	351	368	603	486	**494**

1971-1998 Summary

Minimum	507	626	378	107	37	1	45	10	7	31	278	492	**311**
Maximum	2,261	3,345	2,849	5,178	5,739	5,358	4,672	2,777	1,713	1,914	2,377	2,056	**2,474**
Mean	999	1,125	1,176	1,644	2,757	2,404	1,320	724	593	529	1,071	1,084	**1,285**
Median	931	1,012	1,033	1,565	2,994	2,726	735	536	494	409	1,120	1,013	**1,431**
Std. Dev.	356	613	608	1214	1874	1950	1383	565	452	457	464	423	**625**

TABLE C-6. MONTHLY RIO GRANDE FLOWS AT SAN MARCIAL, 1943-1998

Append B All Gages\Table C-6 San Marcial

Appendix D

Summary of Simulated Rio Grande Streamflows and SJC Loss Factors Used in the Analysis of No Action and DWP Alternatives

Table D-1 Summary Statistics for Simulated RG-960 River Flows (cfs), 2006-2040

		Cochiti	San Felipe	Abq	Isleta*	Bernardc	San Acacia	San Marcial
Minimums	January	428	462	441	710	439	534	479
	February	493	553	551	813	333	558	594
	March	437	545	434	702	152	214	346
	April	268	365	81	350	12	31	82
	May	325	338	0	226	0	0	19
	June	332	353	0	175	0	0	0
	July	208	320	0	178	0	38	32
	August	211	386	0	257	0	0	0
	September	121	206	0	260	0	0	0
	October	213	291	0	226	0	6	5
	November	368	441	355	624	277	347	345
	December	424	463	434	704	439	525	513
Maximums	January	2,245	2,163	2,135	2,395	2,246	2,601	2,236
	February	3,611	3,666	3,511	3,770	3,660	3,797	3,320
	March	2870	3055	2767	3026	2743	3081	2824
	April	6,324	6,130	6,318	6,577	5,145	5,737	5,156
	May	6,108	6,167	6,256	6,514	5,893	6,063	5,719
	June	6,215	6,544	6,087	6,344	6,167	5,602	5,335
	July	5,654	5,990	5,409	5,663	5,249	4,556	4,652
	August	3,692	3,675	3,428	3,688	2,904	3,443	2,761
	September	1,641	1,786	1,530	1,790	1,394	2,080	1,697
	October	2,047	1,432	1,787	2,054	1,860	1,870	1,904
	November	1,879	2,073	2,279	2,538	2,117	2,620	2,352
	December	1,785	1,966	2,250	2,510	2,069	2,181	2,031
Means	January	823	869	866	1,128	917	967	966
	February	937	991	967	1,229	986	1,078	1,040
	March	1179	1265	1187	1449	1014	1027	1058
	April	1,726	1,781	1,661	1,923	1,299	1,292	1,301
	May	2,853	2,892	2,796	3,053	2,534	2,516	2,351
	June	2,657	2,778	2,440	2,690	2,151	2,061	2,027
	July	1,527	1,689	1,320	1,570	1,078	1,115	1,131
	August	773	905	603	864	391	627	653
	September	616	727	440	701	353	624	607
	October	567	664	409	669	352	516	532
	November	875	970	951	1,214	987	1,066	1,034
	December	897	957	947	1,209	990	1,060	1,037
Medians	January	700	754	778	1,036	829	831	861
	February	774	849	769	1,032	840	908	883
	March	1099	1135	1092	1359	810	770	861
	April	1,418	1,431	1,437	1,706	1,298	1,138	1,158
	May	2,554	2,657	2,673	2,927	2,541	2,586	2,241
	June	2,238	2,255	2,008	2,262	1,367	1,207	1,287
	July	891	981	659	927	365	346	575
	August	695	807	501	760	287	516	519
	September	508	670	290	557	214	533	563
	October	544	655	395	664	298	326	408
	November	843	1,039	1,012	1,278	1,088	1,182	1,119
	December	751	790	782	1,051	843	904	895
Standard Deviations	January	355	350	364	365	369	384	357
	February	597	613	621	620	655	638	561
	March	537	539	563	563	612	676	574
	April	1,289	1,280	1,363	1,363	1,224	1,293	1,179
	May	2,077	2,079	2,267	2,272	2,219	2,237	2,037
	June	2,100	2,155	2,225	2,238	2,187	2,089	1,994
	July	1,501	1,564	1,516	1,526	1,469	1,414	1,351
	August	616	590	604	604	542	576	507
	September	367	375	398	399	379	582	455
	October	351	269	363	366	409	478	443
	November	377	423	432	432	431	458	427
	December	396	416	449	448	434	421	420
Annual Mean	2006-2040	1,286	1,375	1,216	1,475	1,087	1,162	1,144

Table D-2. Summary Statistics for Simulated RG-960 River Flows (cfs), 2006-2060

		Cochiti	San Felipe	Abq	Isleta*	Bernardo	San Acacia	San Marcial
Minimums	January	428	462	441	710	439	534	479
	February	493	553	545	813	333	558	594
	March	437	545	434	702	152	214	346
	April	268	365	81	350	12	31	82
	May	325	338	0	226	0	0	19
	June	332	353	0	175	0	0	0
	July	208	320	0	178	0	38	32
	August	211	386	0	257	0	0	0
	September	121	206	0	260	0	0	0
	October	213	291	0	226	0	6	5
	November	331	389	101	365	155	347	256
	December	424	463	434	704	439	525	470
Maximums	January	2,245	2,163	2,135	2,397	2,248	2,604	2,238
	February	3,611	3,666	3,511	3,773	3,662	3,800	3,322
	March	2870	3055	2767	3029	2745	3083	2826
	April	6,324	6,130	6,318	6,579	5,147	5,740	5,158
	May	6,108	6,167	6,256	6,514	5,893	6,065	5,721
	June	6,215	6,544	6,087	6,347	6,172	5,606	5,339
	July	5,654	5,990	5,409	5,668	5,254	4,560	4,655
	August	3,692	3,675	3,428	3,690	2,906	3,444	2,762
	September	1,641	1,786	1,530	1,792	1,396	2,082	1,699
	October	2,047	1,432	1,787	2,054	1,860	1,872	1,904
	November	1,879	2,073	2,279	2,541	2,119	2,622	2,355
	December	1,785	1,966	2,250	2,512	2,071	2,184	2,033
Means	January	830	878	881	1,149	935	990	976
	February	991	1,043	1,020	1,288	1,055	1,144	1,099
	March	1256	1346	1263	1531	1122	1139	1147
	April	1,996	2,055	1,927	2,195	1,559	1,560	1,546
	May	3,171	3,213	3,093	3,358	2,828	2,814	2,644
	June	3,014	3,133	2,782	3,042	2,487	2,387	2,346
	July	1,660	1,830	1,451	1,711	1,208	1,250	1,276
	August	829	970	665	933	462	681	707
	September	654	774	482	749	382	641	612
	October	577	681	429	695	382	516	542
	November	893	987	967	1,235	1,020	1,119	1,060
	December	913	977	969	1,237	1,021	1,102	1,060
Medians	January	700	772	778	1,046	851	848	902
	February	836	849	770	1,033	841	929	948
	March	1162	1215	1120	1383	981	987	979
	April	1,856	1,888	2,043	2,316	1,644	1,647	1,492
	May	3,501	3,604	3,642	3,927	3,464	3,291	2,980
	June	3,416	3,408	3,276	3,535	2,917	2,701	2,633
	July	902	1,091	677	945	520	589	699
	August	755	839	538	805	319	509	520
	September	513	681	307	567	215	527	555
	October	511	655	373	634	298	326	399
	November	849	1,035	996	1,268	1,088	1,183	1,116
	December	796	892	819	1,088	861	1,025	951
Standard Deviations	January	365	356	361	362	372	393	355
	February	656	674	679	681	712	700	613
	March	578	579	602	605	649	714	606
	April	1,360	1,343	1,413	1,414	1,275	1,346	1,234
	May	1,998	1,996	2,148	2,155	2,116	2,131	1,952
	June	2,089	2,139	2,187	2,199	2,157	2,066	1,971
	July	1,550	1,616	1,564	1,572	1,522	1,461	1,395
	August	644	618	639	641	584	641	548
	September	376	383	416	418	398	604	451
	October	375	279	380	384	447	495	464
	November	378	423	442	443	437	478	446
	December	367	391	427	427	410	399	411
Annual Mean	2006-2060	1,399	1,491	1,327	1,593	1,204	1,278	1,251

Table D-3. Summary Statistics for Simulated DWP River Flows (cfs), 2006-2040

		Cochiti	San Felipe	Abq	Isleta*	Bernardo	San Acacia	San Marcial
Minimum	January	495	528	412	686	416	512	475
	February	565	619	521	793	309	545	570
	March	504	612	404	676	128	189	322
	April	268	365	117	384	2	21	72
	May	325	338	0	254	0	6	40
	June	332	353	0	201	0	0	0
	July	208	320	0	204	0	21	15
	August	211	386	26	287	0	0	0
	September	121	206	28	296	4	7	13
	October	213	343	0	265	8	46	42
	November	434	508	326	599	254	325	323
	December	491	530	408	682	417	503	509
Maximum	January	2,311	2,230	2,112	2,406	2,256	2,612	2,246
	February	3,677	3,733	3,488	3,782	3,671	3,808	3,331
	March	2936	3122	2744	3035	2751	3089	2832
	April	6,391	6,196	6,293	6,578	5,146	5,738	5,157
	May	6,174	6,234	6,232	6,511	5,890	6,060	5,716
	June	6,281	6,611	6,058	6,331	6,148	5,585	5,321
	July	5,727	6,063	5,377	5,641	5,232	4,541	4,640
	August	3,758	3,742	3,402	3,686	2,902	3,441	2,760
	September	1,707	1,853	1,504	1,791	1,395	2,074	1,699
	October	2,113	1,498	1,764	2,065	1,869	1,876	1,912
	November	1,946	2,140	2,256	2,549	2,127	2,629	2,362
	December	1,851	2,033	2,227	2,521	2,080	2,192	2,042
Mean	January	893	940	840	1,130	918	969	967
	February	1,008	1,061	940	1,230	987	1,079	1,041
	March	1250	1336	1160	1448	1013	1026	1058
	April	1,793	1,848	1,637	1,921	1,297	1,290	1,299
	May	2,910	2,950	2,776	3,056	2,532	2,516	2,353
	June	2,715	2,835	2,420	2,687	2,147	2,060	2,027
	July	1,588	1,750	1,295	1,564	1,072	1,111	1,128
	August	834	966	582	863	389	627	653
	September	671	783	425	710	358	629	612
	October	626	723	392	681	360	525	541
	November	946	1,041	925	1,215	988	1,067	1,035
	December	968	1,028	920	1,211	992	1,062	1,038
Median	January	777	829	753	1,041	823	833	865
	February	840	916	737	1,029	839	908	890
	March	1184	1224	1071	1357	811	767	861
	April	1,484	1,498	1,416	1,712	1,303	1,143	1,148
	May	2,625	2,724	2,636	2,901	2,517	2,585	2,240
	June	2,309	2,326	1,970	2,229	1,339	1,182	1,265
	July	966	1,048	633	899	355	339	572
	August	761	874	474	756	281	516	550
	September	575	743	265	561	205	534	565
	October	611	721	366	644	290	349	407
	November	911	1,106	989	1,280	1,094	1,172	1,131
	December	821	864	758	1,026	829	912	893
Standard Deviation	January	355	350	367	369	373	387	361
	February	595	612	622	625	659	642	565
	March	535	537	566	568	617	681	579
	April	1,292	1,283	1,361	1,362	1,224	1,293	1,179
	May	2,093	2,095	2,258	2,259	2,213	2,229	2,028
	June	2,114	2,170	2,217	2,226	2,179	2,079	1,985
	July	1,510	1,573	1,513	1,519	1,466	1,411	1,348
	August	626	599	597	598	540	577	507
	September	384	392	385	387	372	574	447
	October	363	282	353	356	406	470	436
	November	377	424	433	433	433	461	429
	December	398	417	451	451	436	424	422
Annual Mean	2006-2040	1,351	1,439	1,193	1,476	1,087	1,163	1,145

Table D-4. Summary Statistics for Simulated DWP River Flows (cfs), 2006-2060

		Cochiti	San Felipe	Abq	Isleta*	Bernardo	San Acacia	San Marcial
Minimum	January	495	528	412	686	416	512	475
	February	560	619	519	793	309	545	570
	March	504	612	404	676	128	189	322
	April	268	365	117	384	2	21	72
	May	325	338	0	254	0	6	40
	June	332	353	0	201	0	0	0
	July	208	320	0	204	0	21	15
	August	211	386	26	287	0	0	0
	September	121	206	28	296	0	7	13
	October	213	338	0	265	8	46	42
	November	397	456	142	448	233	325	323
	December	491	530	408	682	417	503	488
Maximum	January	2,311	2,230	2,112	2,413	2,263	2,619	2,253
	February	3,677	3,733	3,488	3,790	3,679	3,816	3,338
	March	2936	3122	2744	3043	2759	3096	2839
	April	6,391	6,196	6,293	6,587	5,154	5,746	5,164
	May	6,174	6,234	6,232	6,511	5,890	6,068	5,723
	June	6,281	6,611	6,058	6,342	6,165	5,600	5,333
	July	5,727	6,063	5,377	5,661	5,248	4,555	4,651
	August	3,758	3,742	3,402	3,695	2,910	3,448	2,765
	September	1,707	1,853	1,504	1,800	1,402	2,085	1,705
	October	2,113	1,498	1,764	2,069	1,872	1,883	1,915
	November	1,946	2,140	2,256	2,557	2,135	2,637	2,370
	December	1,851	2,033	2,227	2,529	2,088	2,200	2,049
Mean	January	899	947	856	1,157	942	996	982
	February	1,060	1,112	995	1,295	1,062	1,151	1,106
	March	1325	1415	1238	1536	1127	1144	1152
	April	2,063	2,122	1,903	2,197	1,561	1,562	1,548
	May	3,232	3,274	3,072	3,361	2,828	2,815	2,647
	June	3,074	3,194	2,760	3,041	2,485	2,387	2,346
	July	1,723	1,893	1,426	1,708	1,205	1,248	1,274
	August	892	1,033	643	935	463	683	709
	September	711	831	465	760	390	649	618
	October	636	740	412	711	394	528	553
	November	962	1,057	943	1,243	1,028	1,127	1,068
	December	982	1,047	944	1,245	1,029	1,109	1,067
Median	January	778	839	753	1,055	862	860	912
	February	903	916	744	1,047	846	940	960
	March	1228	1282	1088	1379	991	1000	992
	April	1,922	1,955	2,020	2,309	1,630	1,634	1,480
	May	3,568	3,671	3,619	3,940	3,475	3,301	2,983
	June	3,505	3,497	3,251	3,528	2,912	2,696	2,628
	July	968	1,172	653	942	518	581	690
	August	822	929	512	788	320	516	551
	September	586	747	278	573	211	534	565
	October	578	721	350	632	290	349	407
	November	915	1,102	975	1,280	1,099	1,182	1,131
	December	863	959	798	1,102	881	1,038	969
Standard Deviation	January	365	355	362	366	375	396	358
	February	655	673	680	684	716	704	616
	March	576	578	604	609	654	719	611
	April	1,362	1,345	1,411	1,416	1,277	1,348	1,236
	May	2,010	2,007	2,142	2,146	2,113	2,126	1,946
	June	2,099	2,150	2,182	2,191	2,152	2,060	1,965
	July	1,556	1,622	1,562	1,568	1,520	1,459	1,393
	August	650	624	635	638	584	642	549
	September	390	397	405	409	394	599	445
	October	384	291	372	377	445	489	459
	November	378	423	440	442	437	480	446
	December	368	392	428	429	413	402	413
Annual Mean	2006-2060	1,464	1,556	1,305	1,599	1,209	1,282	1,255

Loss Factors Used for City SJC Water Included in Monthly Flows in Tables D-1 to D-4

Tables D-5 and D-6 summarize the loss factors used in this report and the AWRMS River Model as a basis for estimating SJC water at various locations in the Rio Grande, both in developing and modifying the historical 1971-98 hydrologic baseline; and in future simulations using the AWRMS River Model.

Table D-5 is a summary of loss factors for SJC water in common use by the USBR for management in the Rio Grande basin. The USBR and the Rio Grande Compact Engineering Advisors (Advisors) have developed and agree on year-round loss factors for SJC water purposely released for delivery to points between Heron and the Rio Grande confluence with the Jemez River. The USBR and the Advisors also agree on non-summer loss factors for SJC water to be delivered to Elephant Butte. Note that the loss rates in Table D-5 are relatively low because released SJC water is assumed to "ride on top" of native water. In effect, this means that SJC water incurs losses caused by the larger surface area of the flowing water, but essentially no seepage or other losses.

A summary of the status and past work done in developing the SJC loss factors in Table D-5 is provided in a memorandum from Karl Martin(Martin, 1996), USBR Albuquerque to Bill Miller , New Mexico Interstate Stream Commission and Gary Daves and Norm Gaume, City of Albuquerque, October 10, 1996. The memorandum, entitled *Supporting Documentation for SJC Loss Rates* includes a number of exhibits, historical data, study summaries, flow measurements, estimates of channel and evaporative losses, etc. made over the years by various investigators and agencies in relation to conveyance of SJC water between various points on the Rio Chama and Rio Grande.

The factors in Table D-5 are considered to be appropriate for water rights accounting purposes based on precedence and accepted practice in the Rio Grande basin.

Table D-6a provides loss factors applied to simulated releases of City SJC water between Heron Reservoir and Albuquerque. These are the factors employed in the AWRMS River Model (in the present report) for simulated delivery of SJC water to Albuquerque for the DWP. Note that the Albuquerque loss rates in Table D-6a vary between 0.97 in cooler months to 0.92 in summer months. Extrapolated loss factors from Jemez to Albuquerque based on the year-round rates given in Table D-5 would suggest that 0.97 is appropriate for year-round Albuquerque deliveries. However, in order to ensure a conservative analysis of effects on streamflows at Albuquerque and below, we chose to use the higher loss rates in Table D-6a.

Similarly, conservative loss factors given in Table D-6b were used to adjust the simulated 2006-60 streamflow record for the AWRMS river model in this report to account for:

- River Effects – projected changes in flows below Albuquerque caused by estimated City pumping. It is assumed any loss from the river near Albuquerque due to City pumping is native water and, therefore, the effects on downstream gages must be accounted using 'non-SJC' loss factors;
- Return Flow – projected changes in flows below Albuquerque from wastewater returns that are based on projections of future water demands. This is accounted as 'native' water using 'non-SJC' loss factors;
- Additional City SJC Releases – projected changes in flows below Albuquerque due to the residual effects from past pumping over the 2006-16 period. These effects which will be

offset with releases of additional City SJC water from Abiquiu storage over the 2006-16 period amount to more than 90,000 ac-ft are summarized in Table E-2, column 20.

Table D-6c summarizes loss factors that were used to adjust the historical 1971-98 record by accounting for City SJC water at various locations on the Rio Grande. Note that two types of loss factors are applied:

- Non-Irrigation Loss Factors – applied to all historical releases made for specific deliveries for other than MRGCD irrigation; these are generally consistent with those in Table D-5;
- Irrigation Loss Factors – applied to all water released to MRGCD through leases, contracts, borrowing, or other arrangements. These loss factors are generally consistent with typical MRGCD diversions and consumption via irrigated acreages served by each of the diversions at Cochiti, Angostura, Isleta, and San Acacia. Note that at the San Acacia gage and below, their is no SJC water (i.e., loss factor of zero) in keeping with the Law of the River that SJC water has to be consumptively used above Elephant Butte Reservoir.

SJ-C LOSS FACTORS AND LAGS

FROM ↓ / TO →	EL VADO	ABIQUIU	OTOWI	COCHITI	JEMEZ
HERON	1.0000 *no lag*	0.9890 *1 day*	0.9800 *2 day*	0.9767 *2 day*	0.9765 *2 day*
EL VADO		0.9890 *1 day*	0.9800 *2 day*	0.9767 *2 day*	0.9765 *2 day*
ABIQUIU			0.9910 *1 day*	0.9877 *1 day*	0.9875 *1 day*
COCHITI					0.9998 *1 day*

TO Elephant Butte for ↓ / FROM →	Heron & El Vado *(5 day lag)* Condition		Abiquiu *(4 day lag)* Condition		Cochiti *(3 day lag)* Condition	
	A	B	A	B	A	B
JAN	0.944	0.953	0.955	0.964	0.967	0.976
FEB	0.939	0.949	0.950	0.960	0.962	0.972
MAR	0.925	0.939	0.936	0.950	0.948	0.962
APR	0.912	0.930	0.923	0.941	0.935	0.953
MAY	0.905	0.925	0.917	0.936	0.928	0.948
JUN	---NA---	---NA---	---NA---	---NA---	---NA---	---NA---
JUL	---NA---	---NA---	---NA---	---NA---	---NA---	---NA---
AUG	---NA---	---NA---	---NA---	---NA---	---NA---	---NA---
SEP	---NA---	---NA---	---NA---	---NA---	---NA---	---NA---
OCT	0.931	0.944	0.942	0.955	0.954	0.967
NOV	0.940	0.949	0.951	0.960	0.963	0.972
DEC	0.944	0.953	0.955	0.964	0.967	0.976

Condition A: RG flow 400 to 1400 cfs. SJ-C flow 0 to 2000 cfs. RG+SJ-C <=3000 cfs Ref. 1/85 USBR report.

Condition B: RG flow 400 to 1400 cfs. SJ-C flow 0 to 1400 cfs. RG+SJ-C <=1800 cfs Flows routed through low flow conveyance channel. Ref 1/85 USBR repo

Table D-5. USBR Loss Rates for SJC Releases in Rio Chama and Rio Grande

Table D-6. (a) Loss Factors for Heron to Albuquerque SJC Releases for DWP

Month	Heron	Otowi	Cochiti	San Felipe	Albuquerque
1	1.00	0.98	0.98	0.98	0.97
2	1.00	0.98	0.98	0.98	0.97
3	1.00	0.98	0.98	0.98	0.97
4	1.00	0.98	0.98	0.98	0.96
5	1.00	0.98	0.98	0.98	0.95
6	1.00	0.98	0.98	0.98	0.93
7	1.00	0.98	0.98	0.98	0.92
8	1.00	0.98	0.98	0.98	0.92
9	1.00	0.98	0.98	0.98	0.92
10	1.00	0.98	0.98	0.98	0.95
11	1.00	0.98	0.98	0.98	0.97
12	1.00	0.98	0.98	0.98	0.97

(b) Loss Factors Used to Adjust Simulated Record for Changes in City Return Flow, River Effects, and Additional City SJC Releases

Month	Heron	Otowi	Cochiti	San Felipe	Albuq-uerque	Bernardo	San Acacia	San Marcial
1	1.00	0.98	0.98	0.98	0.97	0.92	0.91	0.89
2	1.00	0.98	0.98	0.98	0.97	0.92	0.91	0.89
3	1.00	0.98	0.98	0.98	0.97	0.92	0.91	0.89
4	1.00	0.98	0.97	0.97	0.94	0.87	0.83	0.79
5	1.00	0.98	0.96	0.96	0.91	0.81	0.76	0.70
6	1.00	0.98	0.96	0.95	0.88	0.76	0.68	0.60
7	1.00	0.98	0.95	0.94	0.85	0.70	0.60	0.50
8	1.00	0.98	0.95	0.94	0.85	0.70	0.60	0.50
9	1.00	0.98	0.95	0.94	0.85	0.70	0.60	0.50
10	1.00	0.98	0.96	0.96	0.91	0.81	0.76	0.70
11	1.00	0.98	0.98	0.98	0.97	0.92	0.91	0.89
12	1.00	0.98	0.98	0.98	0.97	0.92	0.91	0.89

(c) Loss Factors Used to Estimate Historical City SJC Water at Locations Below Otow

Location	Non-irrigation Loss Factor[a]	Irrigation Loss Factor[a]
Otowi	1.00	1.00
Cochiti Lake Outlet (after diversion for MRGCD)	0.99	0.90
San Felipe Gage	0.99	0.88
Albuquerque Gage	0.95	0.75
San Acacia Gage	0.91	0[b]

[a] Percent of SJC flow remaining beginning at Otowi.
[b] Assumes all SJC water diverted above gage.

Appendix E

Water Balance Summary of DWP and No Action Alternatives, 2006-60

Guide to Tables E-1 and E-2 (Appendix E)

Tables E-1 and E-2 include results of computer runs made on the OSE interim ground-water model for the No Action and DWP scenarios. The tables include estimates of river seepage, estimates of well pumpage, wastewater return flows, the effects of other city water projects, etc. The key result of these simulations is the “net effect” on the Rio Grande (column 18). The following is a column by column summary to the results provided in Tables E-1 and E-2. All results are in terms of ac-ft.

Year (1)

The year or projected year of the simulation.

Aquifer Pumping (2)

The City ground-water withdrawals for the scenario.

Industrial Reuse (3)

The quantity of water provided for irrigation and industrial reuse from the nonpotable industrial reuse project. It is assumed that this water offsets demand for deep aquifer ground water and that reusing this water will reduce return flows. This project has been constructed and begin operation in the year 2000.

Nonpotable River Use (4)

The quantity of water provided for irrigation and industrial use from the North I-25 nonpotable project. Water will be diverted from the Rio Grande through subsurface collectors. This project is scheduled to begin operation in 2004 and is assumed to offset demand for deep aquifer ground water.

Southside Reclaimed Effluent (5)

The quantity of water to be reused from the City's Southside Wastewater Reclamation Plant (SWRP) for nonpotable irrigation use. It is assumed that this water offsets demand for deep aquifer ground water and that reusing this water will reduce return flows. This project is scheduled to begin operation in 2005.

Shallow Ground Water (6)

This quantity of water estimated from the shallow ground-water project, where shallow ground-water pumping will be utilized for irrigation. The shallow ground-water project is scheduled to begin operation in 2005.

Mesa del Sol Reclaimed Effluent (7)

The quantity of water to be reused from the City's Southside Wastewater Reclamation Plant for nonpotable irrigation use in the Mesa del Sol area. The Mesa del Sol project is scheduled to begin operation in 2010. The Mesa del Sol Project will reduce return flow.

Total Nonpotable (8)

This column sums the total quantity of water provided to offset demands through the nonpotable projects (Industrial Reuse, Nonpotable River Use, Southside Reclaimed Effluent, Shallow Ground Water, and Mesa del Sol Reclaimed Effluent columns).

DWP River Supply (9)

This column is the quantity of water to be diverted by the DWP (0 for the No Action alternative).

Total Demand/Supply (10)

The total City demand in any given year. These demands are met through ground-water withdrawals and the nonpotable projects.

Ground-water Return (11)

The amount of ground water that is returned at the City's SWRP outfall. Ground-water returns are the amount of water returned after all native surface water diverted has been returned.

River Return (12)

The native river return at the City's SWRP outfall (zero for No Action scenario).

Return Flow to WWTP 54% (13)

This column is the total return flow based on the historic relationship with overall demand.

Return Flow to River (14)

The return flow to the SWRP is reduced in this column to reflect the effects of the nonpotable projects such as the Industrial Reuse project. This project takes water that would be discharged to the sanitary sewer and reuses it, therefore reducing returns to the river.

Total Surface Water Diversion (15)

This column sums the quantity of surface diversion (surface water supply column) and the diversions for nonpotable river use to arrive at a net diversion of surface water.

OSE River Effects (16)

The OSE interim Middle Rio Grand Administrative Area model calculated river effects due to City pumping. The OSE model was run with and without City pumping and volumetric budgets were subtracted to arrive at the City's effect.

Net Effect (17)

The net effect is the actual return flow minus the total surface water diversion minus the river effects plus any SJC release. This number is calculated to ensure that the City holds sufficient surface water rights for all water consumed in a given year.

Excess Return Flow (18)

This is the quantity of the City's vested and acquired rights remaining after offsets have been made against net effect. In years when this column is negative, the City would be required to make up the difference with releases of SJC water.

Project SJC Release (19)

This is the annual quantity of SJC water released to meet DWP and nonpotable demands.

Additional SJC Release (20)

Additional SJC water released from storage to meet water rights requirements.

	Demands/Supply									Return Flows				Surface Water Effects					
		Non Potable																	
Year (1)	Aquifer Pumping (2)	Industrial Reuse (3)	Non-potable River Use (4)	Southside Reclaimed Effluent (5)	Shallow Groundwater (6)	Mesa Del Sol Reclaimed Effluent (7)	Total Nonpotable (8)	DWP River Supply (9)	Total Demand/ Supply (10)	Groundwater Return (11)	River Return (12)	Return Flow to WWTP 54% (13)	Return Flow to River (14)	Total Surface Water Diversion (15)	OSE River Effects (16)	Net Effect (17)	Excess Return Flow (18)	Project SJC Release (19)	Additional SJC Release (20)
1993	123,764	0	0	0	0	0	0	0	123,764	58,831	0	58,820	58,831	0	66,661	(7,830)	16,189	0	0
1994	124,542	0	0	0	0	0	0	0	124,542	60,689	0	58,820	60,689	0	68,629	(7,939)	16,080	0	0
1995	125,133	0	0	0	0	0	0	0	125,133	60,218	0	59,831	60,218	0	69,464	(9,246)	14,774	0	0
1996	120,649	0	0	0	0	0	0	0	120,649	58,107	0	57,950	58,107	0	70,832	(12,724)	11,295	0	0
1997	110,834	0	0	0	0	0	0	0	110,834	58,609	0	58,559	58,609	0	70,747	(12,137)	11,882	0	0
1998	114,039	0	0	0	0	0	0	0	114,039	60,705	0	60,696	60,705	0	71,238	(10,533)	13,487	0	0
1999	110,969	0	0	0	0	0	0	0	110,969	59,762	0	59,754	59,762	0	71,937	(12,175)	11,845	0	0
2000	115,460	0	0	0	0	0	0	0	115,460	58,152	0	57,973	58,152	0	72,839	(14,687)	9,333	0	0
2001	111,392	896	0	0	0	0	896	0	112,288	56,901	0	60,636	56,901	0	73,432	(16,531)	7,488	0	0
2002	107,758	896	0	0	0	0	896	0	108,654	57,777	0	58,673	57,777	0	74,075	(16,297)	7,722	0	0
2003	111,156	896	0	0	0	0	896	0	112,052	59,612	0	60,508	59,612	0	74,942	(15,330)	8,690	0	0
2004	109,594	896	1,187	0	0	0	2,083	0	111,677	59,410	0	60,306	59,410	1,117	75,437	(16,027)	7,992	1,117	0
2005	107,298	896	3,038	0	0	0	3,934	0	111,232	59,170	0	60,066	59,170	2,968	75,706	(16,536)	7,484	2,968	0
2006	108,431	896	2,093		0	0	2,989	0	111,420	59,416	0	60,312	59,416	2,023	76,245	(12,379)	11,640	2,023	0
2007	107,314	896	900	2,455	0	0	4,251	0	111,564	57,189	0	60,540	57,189	830	76,580	(14,941)	9,079	830	0
2008	105,191	896	3,038	2,455	0	0	6,389	0	111,580	57,352	0	60,703	57,352	2,968	76,734	(14,932)	9,088	2,968	0
2009	105,555	896	2,697	2,455	0	0	6,048	0	111,603	57,523	0	60,874	57,523	2,627	77,063	(15,090)	8,930	2,627	0
2010	102,146	896	3,038	2,455	930	2,095	9,414	0	111,560	55,569	0	61,015	55,569	2,968	77,023	(17,004)	7,016	2,968	0
2011	102,223	896	2,877	2,455	930	2,095	9,253	0	111,475	55,691	0	61,137	55,691	2,807	77,326	(17,184)	6,835	2,807	0
2012	103,049	896	1,934	2,455	930	2,095	8,310	0	111,359	55,801	0	61,247	55,801	1,864	77,687	(17,436)	6,584	1,864	0
2013	102,228	896	2,552	2,455	930	2,095	8,928	0	111,156	55,869	0	61,315	55,869	2,482	77,870	(17,551)	6,469	2,482	0
2014	101,492	896	3,038	2,455	930	2,095	9,414	0	110,906	55,916	0	61,362	55,916	2,968	77,958	(17,592)	6,428	2,968	0
2015	101,368	896	2,877	2,455	930	2,095	9,253	0	110,621	55,949	0	61,395	55,949	2,807	78,042	(17,644)	6,376	2,807	0
2016	103,061	896	2,697	2,455	930	2,095	9,073	0	112,134	56,788	0	62,234	56,788	2,627	78,290	(21,501)	2,518	2,627	0
2017	104,222	896	3,038	2,455	930	2,095	9,414	0	113,636	57,622	0	63,068	57,622	2,968	78,598	(20,976)	3,044	2,968	0
2018	105,731	896	3,038	2,455	930	2,095	9,414	0	115,145	58,459	0	63,905	58,459	2,968	79,054	(20,594)	3,425	2,968	0
2019	107,240	896	3,038	2,455	930	2,095	9,414	0	116,654	59,297	0	64,743	59,297	2,968	79,535	(20,238)	3,781	2,968	0
2020	108,749	896	3,038	2,455	930	2,095	9,414	0	118,163	60,135	0	65,581	60,135	2,968	80,128	(19,993)	4,027	2,968	0
2021	110,250	896	3,038	2,455	930	2,095	9,414	0	119,664	60,968	0	66,414	60,968	2,968	80,791	(19,823)	4,196	2,968	0
2022	111,751	896	3,038	2,455	930	2,095	9,414	0	121,165	61,800	0	67,246	61,800	2,968	81,482	(19,682)	4,338	2,968	0
2023	113,251	896	3,038	2,455	930	2,095	9,414	0	122,665	62,633	0	68,079	62,633	2,968	82,047	(19,413)	4,606	2,968	0
2024	116,939	896	900	2,455	930	2,095	7,276	0	124,215	63,493	0	68,939	63,493	830	82,854	(19,361)	4,659	830	0
2025	118,440	896	900	2,455	930	2,095	7,276	0	125,715	64,326	0	69,772	64,326	830	83,603	(19,277)	4,743	830	0
2026	119,940	896	900	2,455	930	2,095	7,276	0	127,216	65,159	0	70,605	65,159	830	84,323	(19,164)	4,856	830	0
2027	119,254	896	3,038	2,455	930	2,095	9,414	0	128,668	65,965	0	71,411	65,965	2,968	84,831	(18,867)	5,153	2,968	0
2028	120,754	896	3,038	2,455	930	2,095	9,414	0	130,168	66,797	0	72,243	66,797	2,968	85,485	(18,688)	5,332	2,968	0
2029	122,255	896	3,038	2,455	930	2,095	9,414	0	131,669	67,630	0	73,076	67,630	2,968	86,179	(18,549)	5,471	2,968	0
2030	123,755	896	3,038	2,455	930	2,095	9,414	0	133,169	68,463	0	73,909	68,463	2,968	86,919	(18,456)	5,564	2,968	0
2031	125,239	896	3,038	2,455	930	2,095	9,414	0	134,653	69,286	0	74,732	69,286	2,968	87,684	(18,398)	5,622	2,968	0
2032	126,722	896	3,038	2,455	930	2,095	9,414	0	136,136	70,110	0	75,556	70,110	2,968	88,447	(18,338)	5,682	2,968	0
2033	128,206	896	3,038	2,455	930	2,095	9,414	0	137,620	70,933	0	76,379	70,933	2,968	89,212	(18,279)	5,740	2,968	0
2034	130,656	896	2,093	2,455	930	2,095	8,469	0	139,125	71,768	0	77,214	71,768	2,023	90,085	(18,317)	5,702	2,023	0
2035	133,360	896	900	2,455	930	2,095	7,276	0	140,636	72,607	0	78,053	72,607	830	90,986	(18,379)	5,640	830	0
2036	132,656	896	3,038	2,455	930	2,095	9,414	0	142,070	73,403	0	78,849	73,403	2,968	91,613	(18,210)	5,810	2,968	0
2037	134,489	896	2,697	2,455	930	2,095	9,073	0	143,562	74,231	0	79,677	74,231	2,627	92,405	(18,174)	5,846	2,627	0
2038	135,623	896	3,038	2,455	930	2,095	9,414	0	145,037	75,050	0	80,496	75,050	2,968	93,154	(18,105)	5,915	2,968	0
2039	137,272	896	2,877	2,455	930	2,095	9,253	0	146,525	75,875	0	81,321	75,875	2,807	93,971	(18,096)	5,923	2,807	0
2040	139,720	896	1,934	2,455	930	2,095	8,310	0	148,030	76,710	0	82,156	76,710	1,864	94,868	(18,157)	5,862	1,864	0
2041	140,520	896	2,552	2,455	930	2,095	8,928	0	149,448	77,497	0	82,943	77,497	2,482	95,659	(18,161)	5,858	2,482	0
2042	141,455	896	3,038	2,455	930	2,095	9,414	0	150,869	78,286	0	83,732	78,286	2,968	96,455	(18,169)	5,851	2,968	0
2043	143,052	896	2,877	2,455	930	2,095	9,253	0	152,305	79,083	0	84,529	79,083	2,807	97,358	(18,275)	5,745	2,807	0
2044	144,668	896	2,697	2,455	930	2,095	9,073	0	153,741	79,880	0	85,326	79,880	2,627	98,214	(18,334)	5,686	2,627	0
2045	145,751	896	3,038	2,455	930	2,095	9,414	0	155,165	80,671	0	86,117	80,671	2,968	99,019	(18,348)	5,671	2,968	0
2046	147,184	896	3,038	2,455	930	2,095	9,414	0	156,598	81,466	0	86,912	81,466	2,968	99,794	(18,328)	5,692	2,968	0
2047	148,616	896	3,038	2,455	930	2,095	9,414	0	158,030	82,261	0	87,707	82,261	2,968	100,617	(18,356)	5,664	2,968	0
2048	150,048	896	3,038	2,455	930	2,095	9,414	0	159,462	83,055	0	88,501	83,055	2,968	101,459	(18,404)	5,616	2,968	0
2049	151,480	896	3,038	2,455	930	2,095	9,414	0	160,894	83,850	0	89,296	83,850	2,968	102,313	(18,463)	5,557	2,968	0
2050	152,912	896	3,038	2,455	930	2,095	9,414	0	162,326	84,645	0	90,091	84,645	2,968	103,277	(18,631)	5,388	2,968	0
2051	154,310	896	3,038	2,455	930	2,095	9,414	0	163,724	85,421	0	90,867	85,421	2,968	104,288	(18,868)	5,152	2,968	0
2052	155,708	896	3,038	2,455	930	2,095	9,414	0	165,122	86,197	0	91,643	86,197	2,968	105,326	(19,130)	4,890	2,968	0
2053	157,106	896	3,038	2,455	930	2,095	9,414	0	166,520	86,973	0	92,419	86,973	2,968	106,423	(19,450)	4,569	2,968	0
2054	158,504	896	3,038	2,455	930	2,095	9,414	0	167,918	87,749	0	93,195	87,749	2,968	107,567	(19,818)	4,202	2,968	0
2055	159,902	896	3,038	2,455	930	2,095	9,414	0	169,316	88,524	0	93,970	88,524	2,968	108,693	(20,169)	3,851	2,968	0
2056	161,300	896	3,038	2,455	930	2,095	9,414	0	170,714	89,300	0	94,746	89,300	2,968	109,967	(20,666)	3,353	2,968	0
2057	162,698	896	3,038	2,455	930	2,095	9,414	0	172,112	90,076	0	95,522	90,076	2,968	111,190	(21,113)	2,906	2,968	0
2058	164,096	896	3,038	2,455	930	2,095	9,414	0	173,510	90,852	0	96,298	90,852	2,968	112,403	(21,551)	2,468	2,968	0
2059	165,494	896	3,038	2,455	930	2,095	9,414	0	174,908	91,628	0	97,074	91,628	2,968	113,552	(21,924)	2,096	2,968	0
2060	166,892	896	3,038	2,455	930	2,095	9,414	0	176,306	92,404	0	97,850	92,404	2,968	114,685	(22,281)	1,738	2,968	0

TABLE E1-SUMMARY OF HYDROLOGIC EFFECTS UNDER NO ACTION

	Demands/Supply									Return Flows				Surface Water Effects					
		Non Potable																	
Year (1)	Aquifer Pumping (2)	Industrial Reuse (3)	Non-potable River Use (4)	Southside Reclaimed Effluent (5)	Shallow Groundwater (6)	Mesa Del Sol Reclaimed Effluent (7)	Total Nonpotable (8)	DWP River Supply (9)	Total Demand/ Supply (10)	Groundwater Return (11)	River Return (12)	Return Flow to WWTP 54% (13)	Return Flow to River (14)	Total Surface Water Diversion (15)	OSE River Effects (16)	Net Effect (17)	Excess Return Flow (18)	Project SJC Release (19)	Additional SJC Release (20)
1993	123,764	0	0	0	0	0	0	0	123,764	58,831	0	58,820	58,831	0	66,661	(7,830)	16,189	0	0
1994	124,542	0	0	0	0	0	0	0	124,542	60,689	0	58,820	60,689	0	68,629	(7,939)	16,080	0	0
1995	125,133	0	0	0	0	0	0	0	125,133	60,218	0	59,831	60,218	0	69,464	(9,246)	14,774	0	0
1996	120,649	0	0	0	0	0	0	0	120,649	58,107	0	57,950	58,107	0	70,832	(12,724)	11,295	0	0
1997	110,834	0	0	0	0	0	0	0	110,834	58,609	0	58,559	58,609	0	70,747	(12,137)	11,882	0	0
1998	114,039	0	0	0	0	0	0	0	114,039	60,705	0	60,696	60,705	0	71,238	(10,533)	13,487	0	0
1999	110,969	0	0	0	0	0	0	0	110,969	59,762	0	59,754	59,762	0	71,937	(12,175)	11,845	0	0
2000	115,460	0	0	0	0	0	0	0	115,460	58,152	0	57,973	58,152	0	72,839	(14,687)	9,333	0	0
2001	111,392	896	0	0	0	0	896	0	112,288	56,901	0	56,901	56,901	0	73,432	(16,531)	7,488	0	0
2002	107,758	896	0	0	0	0	896	0	108,654	57,777	0	58,673	57,777	0	74,075	(16,297)	7,722	0	0
2003	111,156	896	0	0	0	0	896	0	112,052	59,612	0	60,508	59,612	0	74,942	(15,330)	8,690	0	0
2004	109,594	896	1,187	0	0	0	2,083	0	111,677	59,410	0	60,306	59,410	1,117	75,437	(16,027)	7,992	1,117	0
2005	107,298	896	3,038	0	0	0	3,934	0	111,232	59,170	0	60,066	59,170	2,968	75,706	(16,536)	7,484	2,968	0
2006	30,016	896	2,093		0	0	2,989	78,000	111,004	20,191	39,000	60,087	59,191	80,023	67,157	(24,020)	0	41,023	18,496
2007	44,581	896	900	2,455	0	0	4,251	63,000	111,832	26,334	31,000	60,685	57,334	63,830	65,682	(24,020)	0	31,830	11,878
2008	11,093	896	3,038	2,455	0	0	6,389	94,000	111,482	10,298	47,000	60,649	57,298	96,968	59,902	(24,020)	0	49,968	21,134
2009	18,648	896	2,697	2,455	0	0	6,048	87,000	111,696	16,574	41,000	60,925	57,574	89,627	57,479	(24,020)	0	45,627	15,435
2010	8,047	896	3,038	2,455	930	2,095	9,414	94,000	111,461	8,515	47,000	60,961	55,515	96,968	53,370	(24,020)	0	49,968	16,386
2011	15,966	896	2,877	2,455	930	2,095	9,253	86,000	111,219	12,550	43,000	60,996	55,550	88,807	51,044	(24,020)	0	45,807	10,024
2012	40,317	896	1,934	2,455	930	2,095	8,310	63,000	111,627	24,949	31,000	61,395	55,949	64,864	52,025	(23,627)	393	32,864	0
2013	23,813	896	2,552	2,455	930	2,095	8,928	78,000	110,741	16,640	39,000	61,086	55,640	80,482	48,416	(24,020)	0	41,482	3,307
2014	7,394	896	3,038	2,455	930	2,095	9,414	94,000	110,808	8,862	47,000	61,308	55,862	96,968	42,237	(24,020)	0	49,968	4,905
2015	15,111	896	2,877	2,455	930	2,095	9,253	86,000	110,364	12,806	43,000	61,252	55,806	88,807	39,687	(22,431)	1,589	45,807	0
2016	17,265	896	2,697	2,455	930	2,095	9,073	86,000	112,338	13,902	43,000	62,348	56,902	88,627	37,892	(23,990)	29	45,627	0
2017	10,123	896	3,038	2,455	930	2,095	9,414	94,000	113,537	10,567	47,000	63,013	57,567	96,968	34,609	(24,020)	0	49,968	22
2018	11,632	896	3,038	2,455	930	2,095	9,414	94,000	115,046	11,405	47,000	63,851	58,405	96,968	32,748	(21,344)	2,676	49,968	0
2019	13,142	896	3,038	2,455	930	2,095	9,414	94,000	116,556	12,242	47,000	64,688	59,242	96,968	31,514	(19,272)	4,748	49,968	0
2020	14,651	896	3,038	2,455	930	2,095	9,414	94,000	118,065	13,080	47,000	65,526	60,080	96,968	30,563	(17,482)	6,537	49,968	0
2021	16,151	896	3,038	2,455	930	2,095	9,414	94,000	119,565	13,913	47,000	66,359	60,913	96,968	29,807	(15,894)	8,125	49,968	0
2022	17,652	896	3,038	2,455	930	2,095	9,414	94,000	121,066	14,746	47,000	67,192	61,746	96,968	29,408	(14,662)	9,357	49,968	0
2023	19,153	896	3,038	2,455	930	2,095	9,414	94,000	122,567	15,579	47,000	68,025	62,579	96,968	29,617	(14,038)	9,981	49,968	0
2024	54,207	896	900	2,455	930	2,095	7,276	63,000	124,482	32,642	31,000	69,088	63,642	63,830	37,953	(6,311)	17,709	31,830	0
2025	55,707	896	900	2,455	930	2,095	7,276	63,000	125,983	33,475	31,000	69,921	64,475	63,830	41,559	(9,085)	14,935	31,830	0
2026	57,208	896	900	2,455	930	2,095	7,276	63,000	127,484	34,307	31,000	70,753	65,307	63,830	43,772	(10,465)	13,555	31,830	0
2027	25,155	896	3,038	2,455	930	2,095	9,414	94,000	128,569	18,910	47,000	71,356	65,910	96,968	38,456	(19,547)	4,473	49,968	0
2028	26,953	896	3,038	2,455	930	2,095	9,414	94,000	130,367	19,908	47,000	72,354	66,908	96,968	36,490	(16,583)	7,437	49,968	0
2029	28,156	896	3,038	2,455	930	2,095	9,414	94,000	131,570	20,576	47,000	73,022	67,576	96,968	35,567	(14,991)	9,028	49,968	0
2030	29,657	896	3,038	2,455	930	2,095	9,414	94,000	133,071	21,408	47,000	73,854	68,408	96,968	35,278	(13,869)	10,150	49,968	0
2031	31,140	896	3,038	2,455	930	2,095	9,414	94,000	134,554	22,232	47,000	74,678	69,232	96,968	35,335	(13,104)	10,916	49,968	0
2032	32,624	896	3,038	2,455	930	2,095	9,414	94,000	136,038	23,055	47,000	75,501	70,055	96,968	35,610	(12,555)	11,465	49,968	0
2033	34,107	896	3,038	2,455	930	2,095	9,414	94,000	137,521	23,878	47,000	76,324	70,878	96,968	35,980	(12,102)	11,918	49,968	0
2034	52,241	896	2,093	2,455	930	2,095	8,469	78,000	138,710	32,538	39,000	76,984	71,538	80,023	40,027	(7,489)	16,530	41,023	0
2035	70,628	896	900	2,455	930	2,095	7,276	63,000	140,903	41,755	31,000	78,201	72,755	63,830	44,893	(4,137)	19,882	31,830	0
2036	38,558	896	3,038	2,455	930	2,095	9,414	94,000	141,972	26,348	47,000	78,794	73,348	96,968	41,872	(15,524)	8,496	49,968	0
2037	47,582	896	2,697	2,455	930	2,095	9,073	87,000	143,655	33,282	41,000	79,728	74,282	89,627	42,522	(12,239)	11,780	45,627	0
2038	41,525	896	3,038	2,455	930	2,095	9,414	94,000	144,939	27,995	47,000	80,441	74,995	96,968	41,581	(13,586)	10,434	49,968	0
2039	51,015	896	2,877	2,455	930	2,095	9,253	86,000	146,268	32,733	43,000	81,179	75,733	88,807	42,987	(10,254)	13,766	45,807	0
2040	76,988	896	1,934	2,455	930	2,095	8,310	63,000	148,297	45,859	31,000	82,305	76,859	64,864	47,593	(2,734)	21,285	32,864	0
2041	62,104	896	2,552	2,455	930	2,095	8,928	78,000	149,032	38,267	39,000	82,713	77,267	80,482	47,547	(9,280)	14,739	41,482	0
2042	47,356	896	3,038	2,455	930	2,095	9,414	94,000	150,770	31,232	47,000	83,678	78,232	96,968	45,966	(14,735)	9,285	49,968	0
2043	56,795	896	2,877	2,455	930	2,095	9,253	86,000	152,048	35,941	43,000	84,387	78,941	88,807	46,865	(10,924)	13,095	45,807	0
2044	58,872	896	2,697	2,455	930	2,095	9,073	86,000	153,945	36,994	43,000	85,440	79,994	88,627	47,539	(10,546)	13,474	45,627	0
2045	51,653	896	3,038	2,455	930	2,095	9,414	94,000	155,067	33,616	47,000	86,062	80,616	96,968	46,948	(13,332)	10,688	49,968	0
2046	53,085	896	3,038	2,455	930	2,095	9,414	94,000	156,499	34,411	47,000	86,857	81,411	96,968	46,968	(12,557)	11,462	49,968	0
2047	54,517	896	3,038	2,455	930	2,095	9,414	94,000	157,931	35,206	47,000	87,652	82,206	96,968	47,176	(11,970)	12,050	49,968	0
2048	55,949	896	3,038	2,455	930	2,095	9,414	94,000	159,363	36,001	47,000	88,447	83,001	96,968	47,467	(11,466)	12,553	49,968	0
2049	57,382	896	3,038	2,455	930	2,095	9,414	94,000	160,796	36,796	47,000	89,242	83,796	96,968	47,843	(11,047)	12,972	49,968	0
2050	58,814	896	3,038	2,455	930	2,095	9,414	94,000	162,228	37,590	47,000	90,036	84,590	96,968	48,255	(10,665)	13,355	49,968	0
2051	60,212	896	3,038	2,455	930	2,095	9,414	94,000	163,626	38,366	47,000	90,812	85,366	96,968	48,786	(10,420)	13,600	49,968	0
2052	65,422	896	3,038	2,455	930	2,095	9,414	90,000	164,836	43,038	43,000	91,484	86,038	92,968	49,747	(6,709)	17,311	49,968	0
2053	63,008	896	3,038	2,455	930	2,095	9,414	94,000	166,422	39,918	47,000	92,364	86,918	96,968	49,952	(10,034)	13,985	49,968	0
2054	64,406	896	3,038	2,455	930	2,095	9,414	94,000	167,820	40,694	47,000	93,140	87,694	96,968	50,444	(9,750)	14,269	49,968	0
2055	65,803	896	3,038	2,455	930	2,095	9,414	94,000	169,217	41,470	47,000	93,916	88,470	96,968	50,974	(9,505)	14,515	49,968	0
2056	67,201	896	3,038	2,455	930	2,095	9,414	94,000	170,615	42,246	47,000	94,692	89,246	96,968	51,553	(9,307)	14,713	49,968	0
2057	68,599	896	3,038	2,455	930	2,095	9,414	94,000	172,013	43,021	47,000	95,467	90,021	96,968	52,107	(9,086)	14,934	49,968	0
2058	69,997	896	3,038	2,455	930	2,095	9,414	94,000	173,411	43,797	47,000	96,243	90,797	96,968	52,691	(8,893)	15,126	49,968	0
2059	71,395	896	3,038	2,455	930	2,095	9,414	94,000	174,809	44,573	47,000	97,019	91,573	96,968	53,305	(8,732)	15,288	49,968	0
2060	72,793	896	3,038	2,455	930	2,095	9,414	94,000	176,207	45,349	47,000	97,795	92,349	96,968	53,930	(8,581)	15,438	49,968	0

TABLE E2-SUMMARY OF HYDROLOGIC EFFECTS WITH DWP