Appendix C

HYDROLOGIC MODELING ANALYSIS

Please note in this appendix that the figures refer to the "Preferred Plan," which is the same as the "Preferred Alternative" mentioned in the text. In addition, the information contained in this appendix has not been updated to include or reflect recently approved depletions for the Long Hollow Reservoir Project or the Jicarilla Apache Nation Navajo River Water Supply Project.

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Introduction

This appendix details the analysis process for determining impacts to hydrology from operation of the No Action Alternative, the 250/5000 Alternative (Preferred Alternative), and the 500/5000 Alternative. The results of this modeling effort are also presented.

Understanding the impact of the alternatives on the water resources of the San Juan River basin requires modeling the complex relationships associated with multiple diversion and return flow points in the basin. A number of basin-scale models exist that take hydrologic input data and simulate the behavior of various processes under different sets of water allocation and infrastructure management. A distinguishing feature of these simulation models is their ability to assess water resource system responses over the long term.

There are several best-science river basin simulation models available, any one of which would be appropriate for developing and analyzing San Juan River flow recommendations. RiverWare was selected primarily because of its flexibility and capability to simulate all key features within the San Juan River Basin. RiverWare has been implemented in the San Juan Basin since 1998 in support of assessing the relationship between flow recommendations for endangered fish in the San Juan River and water development. This implementation has been completed by the U.S. Bureau of Reclamation (Reclamation) and Keller-Bliesner Engineering as a consultant for the U.S. Bureau of Indian Affairs (BIA). The application for this analysis is an extension of that work.

Modeling Approach

RiverWare.—RiverWare is a generic hydrologic modeling tool using an object-oriented design and a graphical user interface (GUI) to allow users to develop data-driven and variable time-step models for both planning and operational uses. Because of its flexible and extensible design, it can be readily customized to fit specialized modeling needs for any river system. One of the features of RiverWare is its ability to solve a river basin network (developed by the user with the graphical user interface) with different controllers or solution techniques. Currently, there are three different controllers: simulation, rule-based simulation, and optimization. A fourth controller for water ownership and accounting is currently being developed. RiverWare has been in development since 1993 and is the result of a continuing collaborative effort between the Center for Advanced Decision Support for Water and Environmental Systems at the University of Colorado, Reclamation, and the Tennessee Valley Authority (TVA).

A model of a river system network is constructed by placing objects from a palette onto a work space using the GUI. Objects in RiverWare represent the features of a river basin. The objects supported by RiverWare are storage reservoirs, power reservoirs, pumped storage reservoirs, river reaches, aggregate river reaches, confluences, aggregate diversions for municipal and industrial (M&I) and agricultural demands, canals, groundwater, and data objects. Each object has many slots. Slots are essentially place holders for information associated with that object. For example, a storage reservoir has slots such as inflow, outflow, storage, evaporation, elevation, and volume tables. The slots that are visible depend on the methods that the user selects. Almost all of the objects have several different methods available, thus allowing the user to easily customize the physical behavior of an object. For example, to change how a reservoir computes its evaporation, the user simply selects an appropriate evaporation method from the list of methods on the reservoir object. RiverWare adds the appropriate slots to the object and the user provides the necessary data. The selected method and data control how the reservoir will compute its evaporation. After the objects are put into the work space and the appropriate methods are selected, they can be linked together so information from one object is propagated to another. For example, the outflow of a reservoir could be linked to the inflow of a downstream river reach. By selecting appropriate objects, methods, and linking the objects together, a river basin network is formed.

After the river basin network is complete, the user can take advantage of many features and utilities that make it easy to input, output, view, manipulate, and analyze data in a model. These utilities include the Simulation Control Table, Data Management Interfaces, plotting, snapshot, expression slots on data objects, and the ability to write binary Microsoft Excel spreadsheet files. Simulation Control Tables allow the user to customize views of information in the model and also to run the model and view the updated model run results. Data Management Interfaces provide a way to transport data between a model and external data sources, such as a database or an ASCII file. With the plotting utilities, virtually any information in the model can be easily plotted for analysis and report generation. The snapshot utility provides the user a way to save information from a model run so it can be used to compare with subsequent model runs. Expression slots on data objects provide a powerful way to algebraically manipulate data within the model. Additionally, RiverWare has a robust diagnostics utility for checking for and helping to pinpoint problems.

Current RiverWare applications where the models are operational include the following applications: (1) long-term policy planning model on the Colorado River (rules model with monthly time-step), (2) midterm planning and operations model on Colorado River (24-month simulation model with monthly time-step), (3) daily operational model for Hoover Dam (BOPS, simulation model), (4) operational model for the TVA (TVA, optimization model with 6-hour time-step), (5) Upalco Planning Model (rules model with daily time-step) and (6) San Juan River Model for the San Juan basin (rules model with monthly and pseudo daily time-step). RiverWare models currently under development include the following: (1) Upper Rio Grande Water Operation Basin Model (accounting and rules model with daily time-step), (2) Gunnison River Basin Model (rules model with daily time-step), and (3) Yakima River Basin Models (rules model with both monthly and daily time-steps).

RiverWare Model of the San Juan River.—Hydrologic simulation models, such as RiverWare, are essentially mass balance models operating within a rule-based framework to simulate hydrologic interactions between water sources and their uses. Maintaining a water balance assures that the sum of inflows less the sum of outflows equals the change of storage within the basin. Water inflows consist of natural stream flows, trans-basin inflows (e.g., Dolores Project return flows), and precipitation. Outflows consist of water flowing across the downstream basin boundary (San Juan River at Bluff), consumptive use (crops, M&I, natural vegetation, free water surface evaporation, etc.), and trans-basin diversions (San Juan-Chama). Water storage consists of the water within basin lakes and reservoirs, soils, and groundwater aquifers.

In the San Juan River model[1] only unnatural (man-induced) hydrologic effects are explicitly modeled. The model begins with the natural inflows and natural, ungaged, gains and losses to river reaches. Starting from this basis eliminates the need to model natural hydrologic processes such as rainfall/runoff. Thus, precipitation falling upon natural vegetation, consumptive use by natural vegetation, runoff of excess precipitation, evaporation from the free water surfaces of rivers, etc. are assumed to be reflected in the natural inflows and reach gains and losses and are therefore not modeled. Likewise, it is assumed that precipitation runoff from man-affected areas (agricultural lands, cities, etc.) is not significantly different from natural conditions to warrant explicit modeling treatment.

Thus, the inflows for the simulated water balance of the San Juan River Basin consist of the estimated natural inflows, stream reach gains, and the Dolores Project return flow to the San Juan River Basin. The outflows consist of the man-affected (gaged) flow of the San Juan River at Bluff, consumptive irrigation (irrigated crop evapotranspiration less effective precipitation), M&I depletions, net (in excess of natural) evaporation from manmade reservoirs and stock ponds, and the San Juan-Chama trans-basin diversion. The change in storage is reflected in the difference between beginning and ending reservoir content and groundwater volume. Groundwater storage in the current model includes the underlying NIIP and the irrigation in McElmo and Montezuma creeks. The effects of soil water storage for irrigated lands are assumed to be reflected in the effective rainfall and consumptive irrigation calculations and are not explicitly modeled.

The 1970 to 1993 monthly natural flows expected at 23 gaging stations along the San Juan River and its tributaries above Mexican Hat, Utah, were calculated by Reclamation. The monthly natural flows were estimated by adjusting gaged flows (Hydrosphere, 1998) to account for upstream irrigated crop depletions, reservoir influences (operational and evaporative), trans-basin diversions, M&I uses, and flows directly bypassing the gage. Natural reach gains and losses were calculated as the difference in the natural flow estimates between gaging stations. No lagging of return flows (diversions less depletions) was incorporated except for the three areas underlain by the simulated groundwater storage.

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[1] ***San Juan Basin Model Disclaimer***: Use of the model in the work of the SJRBRIP does not necessarily constitute agreement or approval by individual program participants with the model data, methodologies, or assumptions. Use of the model does not change the responsibilities of the respective States to maintain records of water rights and water use. Official records of water rights and water use are maintained by the State agencies statutorily charged with that responsibility.

Irrigated crop depletions were calculated using the SCS TR21 modified Blaney-Criddle consumptive use less effective precipitation (Soil Conservation Service, 1970). When water supplies are insufficient to meet diversion requirements for full crop demand, shortages are simulated following Reclamation Type I study approach (Reclamation, 1971). Reclamation's XCON program was used to compute both nonshorted and shorted irrigation depletions.

Previous modeling of the San Juan River in support of project authorization and Consultation under Section 7 of the Endangered Species Act (ESA) relied on Colorado River Simulation System (CRSS) estimates of the 1929 to 1974 monthly natural flows at Archuleta, New Mexico, and Bluff. As part of the San Juan River Basin modeling exercise, an analysis of the 1929 to 1974 streamflow record was conducted to determine whether there were differences in the statistical properties of the San Juan River Basin hydrology pre- and post-1974. Statistics were calculated using a 20-year moving window to assess changes in the mean flow and the variability and seasonality of the flows. An investigation of the impacts on reservoir storage needed to meet various target yields and yield failure was also performed. The 1974 to 1993 record was found to exhibit significant differences from the prior record in terms of these criteria. It was a relatively wet period. It was therefore determined that inclusion of the 1929-1973 data would likely lead to more reasonable and more stringent estimates of low flows and drought conditions.

Therefore, the monthly 1970 to 1993 natural flows recalculated by Reclamation as explained above were extended from 1969 back to 1929 using a spatial disaggregation model. The particular disaggregation model used preserves the mean, standard deviation, and one-month lag statistics of the hydrologic series. The model relies on key stations with full periods of record (in this case 1929 to 1993) as drivers for the record extension. The natural flows at Archuleta and Bluff were forced, by adjusting stream reach gains and losses to exactly match the CRSS natural flows at Archuleta and Bluff for the period 1929 to 1969.

The 1935 to 1993 monthly gaged record for the San Juan River at Pagosa Springs, Colorado, served as the key station for stations, including all tributaries, above Navajo Reservoir. The gaged record at Pagosa Springs was extended back to 1929 using the spatial disaggregation method with the 1929 to 1934 CRSS natural flow for the San Juan River near Archuleta as its key station. For stations in the Animas drainage, the Animas River at Durango, Colorado, was the key station for 1929 to 1993. The tributaries entering the San Juan River below Farmington (La Plata, Mancos, and McElmo) were disaggregated using the La Plata River at Hesperus, Colorado, as the key station.

From the full set of natural flows (the 1929 to 1969 extension and the 1970 to 1993 Reclamation natural flows) the gains and losses were calculated for each reach by subtracting the upstream stations from the downstream station. However, for stations along the San Juan River (Farmington, Shiprock, and Four Corners, New Mexico), another method was used to find the gain and loss files. There were two reasons for the change: (1) for this study monthly natural flows at these stations needed to be further disaggregated into daily values, and (2) the daily gage error at these stations could be suppressed by using a different method to find gains and losses.

For these stations along the mainstem of the San Juan River, the monthly natural flows for 1929 to 1969 were estimated by distributing gains and losses between Archuleta and Bluff

(Mexican Hat). The method consisted of subtracting the monthly natural flows of the La Plata River, the Mancos River, McElmo Creek, and the CRSS San Juan River near Bluff from the CRSS natural flow at Archuleta. The net gains and losses in this reach were then distributed among the intermediate stations along the mainstem of the San Juan River. The distribution for each reach was calculated as the mean annual gain or loss using the 1970 to 1993 natural flows for the appropriate station set. The distributions, expressed as a percentage of the total gain or loss by reach, were 0.0% from Archuleta to Farmington, 7.0% from Farmington to Shiprock, 58.7% from Shiprock to Four Corners, and 34.3% from Four Corners to Mexican Hat. Using these percentages, the monthly gain or loss was computed for each intermediate station for years 1929 to 1969. For 1970 to 1993 the gain or loss was found by the difference of Reclamation natural flows.

The RiverWare model of the San Juan River Basin operates on a monthly time-step, simulating the flow at every gaging station for various depletion scenarios (current, depletion base, and various potential future projects). The model determines daily flows for the simulated Navajo Dam releases and the proposed ALP Project Ridges Basin pumping plant only. Monthly flows provided insufficient information to adequately describe the runoff hydrograph (magnitude, duration, timing, and shape) necessary in the flow recommendation process. Thus, it was necessary to temporally disaggregate monthly flows to daily flows for the San Juan River mainstem below Navajo Dam. This was achieved by a daily mass balance on the mainstem computed in a spreadsheet after each RiverWare run. The daily distribution of natural stream reach gains and losses was estimated using the difference between daily gage records. Likewise, the gaged flow records for the Animas, La Plata, and Mancos rivers at their mouths were used to disaggregate the RiverWare simulated monthly flow of each river to daily flow. Simulated monthly diversions and return flows along the mainstem were disaggregated to daily values by distributing the monthly flows into quarter month values. The distributed quarter month flows were then uniformly converted to daily flows.

Irrigation diversions, depletions, return flows, trans-basin diversions, and M&I uses were explicitly represented and modeled in RiverWare for all major San Juan tributaries (San Juan River above Navajo Dam, Piedra, Los Pinos, Animas, La Plata, and Mancos rivers and McElmo Creek). All other tributaries were aggregated into the gains and losses to the reach of the San Juan River into which they flow. The unnatural depletions from these minor tributaries were treated as direct diversions from the San Juan River. Navajo, Ridges Basin, Vallecito, and Florida reservoirs and Jackson Gulch were explicit nodes within the model and their operations were simulated according to rules. Operations of Electra Lake and all other water impoundments, including stock ponds, were ignored. However, the evaporation losses from these facilities were included as depletions from their associated streams.

Several refinements were developed to compensate for peculiarities in the way the natural flow study handled some depletions and the resulting RiverWare configuration. In the natural flow study offstream depletions, remote from the mainstem and major tributaries, were treated as direct diversions from the mainstem. As a result these offstream depletions, both irrigation and non-irrigation, could call on Navajo Reservoir in the model and overdraw the reservoir during simulations. By limiting these offstream depletions to the natural gains occurring within their associated river reach, this problem was avoided. Other refinements included compensation for phreatophyte depletions along the mainstem and adjustments to lag return flows.

The San Juan-Chama project was simulated following the rules of the Authorization Act. Daily bypass flow requirements in the Rio Blanco, Little Navajo, and Navajo rivers were maintained. The maximum single year diversion (270,000 af), maximum total 10-year diversion (1,350,000 af), and capacity of the diversion tunnels were also respected. The diverted water was stored and released from Heron Reservoir, which was also simulated in the San Juan RiverWare model. The release pattern from Heron Reservoir followed the mean call pattern of the current San Juan-Chama contracts.

The ALP Project impacts were simulated in RiverWare by explicitly entering the various project features and defining their operation in the system. To meet daily minimum flow requirements in the Animas River, a daily operation loop was employed to determine allowable pumping to Ridges Basin reservoir. All other computations were completed on a monthly time step.

Before using the San Juan RiverWare model for project analysis, it had to be validated, verified, and calibrated like any model. The configuration of the model was validated by having the model simulate gaged flows from the natural flows and the historical depletions, reservoir releases, and flow routing used to compute the natural flows. This was essentially a back-calculation of the gaged flows from the natural flows. The model configuration was determined to be valid once the simulated flows at all gage points matched the gaged flows.

Once the model configuration was validated, reservoir operation rules were substituted for the historic releases, and the model was rerun. The reservoir operating rules were calibrated so that the end of month reservoir contents closely matched the historical observed contents. Once this match was obtained, rules designed to simulate the Type I shortage were implemented and the full irrigation demands substituted for the historical shorted demands. Again the rules were adjusted until the simulated flows at all gaging stations closely matched the observed gaged flows. Once this was achieved the model was assumed calibrated and verified.

Simulation of reservoir operations, particularly operation to "mimic" natural flows, requires forecasts of reservoir inflows. For forecasting inflows to Vallecito and Lemon reservoirs, the fraction of the deviation of the actual inflow from the mean inflow is added to the mean inflow. The deviation fraction starts small early in the year and approaches 100% when close to the peak runoff month. For the Navajo Reservoir operation simulation, a forecast error approach is used, whereby the mean historical forecast error for each month is predetermined and applied. Operation of Navajo Dam to maximize peak flows also requires forecasting the time of peak runoff for the Animas River, allowing releases from Navajo Dam to match the Animas peak. At this time, a constant peak release date has been utilized, since no significant relationship could be developed for predicting timing of the Animas peak. The required timing of the peak release from Navajo Dam was adjusted to optimize the hydrograph statistics to mimic the 1929 to 1993 period of analysis.

The model in its present configuration represents the best science available to assess the impacts of water development on the ability to meet flow recommendations for endangered fish and to test operating rules designed for that purpose. The presently defined operating rules and model configuration do not indicate availability for substantial additional depletions in the basin with the present flow recommendations. Further modification of the operating rules and/or improvement in the simulation of system operation in the San Juan River would be required to demonstrate the possibility of further development within the limits of the present flow recommendations.

Configuration for No Action Alternative.—RiverWare model representation of the future conditions expected in the San Juan River Basin without implementing flow recommendations is required to establish the "baseline" against which impacts are measured. This condition is called the No Action Alternative and was configured by including all current depletions, all depletions that could occur without further federal action (primarily exercise of state water rights not presently being used as identified by Colorado and New Mexico), and all depletions for which favorable biological opinions did not depend on implementing the action. Since Flow Recommendations would not be met, it was assumed that the ALP Project, completion of blocks 9-11 of NIIP and 3,000 acre-feet of minor depletions via ESA consultation would not occur. Depletions used for the No Action Alternative appear in Table 1. The model uses operating rules to simulate historic 1973 to 1991 reservoir releases. The reservoir filled in 1973 and in 1991, releases were modified to meet the goal of the 7-year research period (1991-1997). The No Action Alternative depletions total about 667,000 acre-feet per year, including Dolores Project[2] return flows in McElmo Creek.

Configuration for the 250/5000 and 500/5000 Alternatives.—Model configuration for the two action alternatives is the same, only varying with minimum Navajo Reservoir releases. Minimum target releases are 250 cfs for the 250/5000 Alternative and 500 cfs for the 500/5000 Alternative. To analyze the impacts to hydrology, the model was configured to simulate the future condition of implementing Flow Recommendations and include all current depletions, all depletions that could occur without further Federal action (primarily exercise of State water rights not presently being used as identified by Colorado and New Mexico), and all depletions which have received a favorable biological opinion. These include 57,100 acre-feet per year for the ALP Project, 120,600 acre-feet per year for completion of blocks 9-11 of NIIP, and 3,000 acre-feet per year for minor depletions via inter-service Section 7 consultation.

The configuration of ALP Project was adjusted to address comments from the New Mexico Interstate Stream Commission(NMISC) to the Draft Supplemental Environmental Impact Statement for the Animas-La Plata Project (DSEIS), Colorado, and New Mexico (Reclamation, 2000). The DSEIS contemplates the Colorado Ute Tribes leasing water under their water rights settlement with Colorado to the San Juan Water Commission in

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[2] The Dolores Project, in the Dolores and San Juan River Basins, was developed by Reclamation for irrigation, M&I, recreation, and fish and wildlife uses.

Table 1.—Summary of San Juan River Basin depletions for each alternative[1, 2, 3]
(November 2005)

Depletion category	No Action Alternative (acre-feet/year)	250/5000 Alternative (acre-feet/year)	500/5000 Alternative (acre-feet/year)
New Mexico depletions			
Navajo lands irrigation depletions			
Navajo Indian Irrigation Project	[4]143,600	[4]280,600	[4]280,235
Hogback	26,163	[5]12,100	[5]12,065
Fruitland	10,233	[5]7,898	[5]7,898
Cudei	900	900	900
Chaco River offstream depletion	[6]2,832	[6]2,832	[6]2,832
Whiskey Creek offstream depletion	[6]523	[6]523	[6]523
Subtotal	184,251	304,853	304,453
Non-Navajo lands irrigation depletions			
Above Navajo Dam – private	738	738	738
Above Navajo Dam – Jicarilla	[7]2,195	[7]2,195	[7]2,195
Animas River	36,711	36,711	36,711
La Plata River	9,739	9,808	9,808
Upper San Juan	9,137	9,137	9,045
Hammond Area	10,268	10,268	10,164
Farmers Mutual Ditch	9,532	9,532	9,532
Jewett Valley	3,088	3,088	3,088
Westwater	110	110	110
Subtotal	81,518	81,587	81,391
Total New Mexico irrigation depletions	265,769	386,440	385,884
Non-irrigation depletions			
Navajo Reservoir evaporation	29,209	27,350	26,274
BHP Navajo Coal Company	39,000	39,000	38,981
San Juan Generating Station	[8]16,200	[8]16,200	[8]16,200
Industrial diversions near Bloomfield	2,500	2,500	2,500
Municipal and industrial uses	8,454	8,454	8,432
Scattered rural domestic uses	[6]1,400	[6]1,400	[6]1,400
Scattered stock ponds and livestock uses	[6]2,200	[6]2,200	[6]2,200
Fish and wildlife	[6]1,400	[6]1,400	[6]1,400
Total New Mexico non-irrigation depletions	100,363	98,504	97,387
San Juan-Chama Project exportation	107,514	107,514	107,514
Unspecified minor depletions	[9]1,500	[10]4,500	[10]4,486
Animas-La Plata Project		13,600	13,600
Jicarilla Apache Nation Navajo River Water Supply Project	[11]6,570	[11]6,570	[11]6,570
Total New Mexico depletions	481,716	617,128	615,401

Table 1.—Summary of San Juan River Basin depletions for each alternative[1, 2, 3] (continued)

Depletion category	No Action Alternative (acre-feet/year)	250/5000 Alternative (acre-feet/year)	500/5000 Alternative (acre-feet/year)
Colorado depletions			
Upstream of Navajo Reservoir			
Upper San Juan	10,858	10,858	10,858
Navajo-Blanco	7,865	7,865	7,865
Piedra	8,098	8,098	8,098
Pine River	71,671	71,671	71,671
Subtotal	98,492	98,492	98,492
Downstream of Navajo Reservoir			
Florida	28,607	28,607	28,607
Animas	25,113	25,119	25,119
La Plata	[12, 13]13,245	[12, 13]13,245	[12, 13]13,245
Long Hollow Reservoir Project	[13]1,339	[13]1,339	[13]1,339
Mancos	19,530	19,532	19,532
McElmo Basin imports	(11,769)	(11,769)	(11,769)
Subtotal	76,065	76,073	76,073
Animas-La Plata Project		43,533	43,523
Total Colorado depletions	174,557	218,098	218,088
Colorado and New Mexico combined depletions	656,273	835,226	833,489
Utah depletion	[6, 14]9,140	[6, 14]9,140	[6, 14]9,140
Arizona depletion	[6]10,010	[6]10,010	[6]10,010
Grand total	675,423	854,376	852,639

[1] The State of New Mexico does not necessarily agree with the depletions shown in terms of constituting evidence of actual water use, water rights, or water availability under the Compact. The SJRBRIP Hydrology Committee uses a hydrology model disclaimer that reads in part, "The model data methodologies and assumptions do not under any circumstances constitute evidence of actual water use, water rights, or water availability under Compact apportionments and should not be construed as binding on any party."

[2] The New Mexico Interstate Stream Commission (NMISC) and the San Juan Water Commission (SJWC) believe there are inconsistencies in depletion calculations (communications from NMISC and SJWC dated April 1 and March 21, 2002, respectively).

[3] It should be noted that full development of State compact water and Indian trust water is not included in this table. Only existing projects and projects with Endangered Species Act and NEPA compliance are included in the depletion table.

[4] Includes 10,600 acre-feet per year of annual groundwater storage. At equilibrium, the No Action Alternative drops to 133,000 acre-feet per year and the action alternatives drop to 270,000 acre-feet per year.

[5] Accounts for 16,420 acre-feet per year transferred from Hogback, including the Hogback Extension, and Fruitland Projects to NIIP.

[6] Indicates offstream depletion accounted for in calculated natural gains. The combined figures for the New Mexico portion include 2,185 acre-feet of historic and existing uses of Jicarilla Apache settlement water rights for scattered off-stream depletions on the reservation.

[7] The Jicarilla Apache Nation recognizes this historic depletion as 2,195 acre-feet, but it was modeled as 2,190 acre-feet on average.

[8] Water contract with the Jicarilla Apache Nation for long-term depletions for the San Juan Generating Station.

[9] 1,500 acre-feet per year of depletion from minor depletions approved by SJRBRIP in 1992.

[10] Includes an additional 3,000 acre-feet per year of depletion from 1999 Intra-Service consultation, a portion of which may be in Colorado. This amount includes 770 acre-feet of water subcontracted by the Jicarilla Apache Nation to "minor contractors" below Navajo Dam.

[11] Jicarilla Apache Nation Navajo River Water Supply Project Biological Opinion lists this depletion as 6,654 acre-feet, but model configuration shows 6,570 acre-feet on average. The model configuration is shown.

[12] Includes the Red Mesa Reservoir Enlargement depletion in the amount of 997 acre-feet.

[13] Long Hollow Reservoir Project Biological Opinion lists this depletion as 1,535 acre-feet. Model configuration shows this as 1,339 acre-feet for Long Hollow Reservoir Project and an additional 198 acre-feet is included in the La Plata category.

[14] 1,705 acre-feet per year San Juan River depletion, 7,435 acre-feet per year offstream depletion.

New Mexico. NMISC does not, at this time, support interstate leasing or marketing of water. To meet this request, Colorado Ute Tribes' depletions in New Mexico were moved to Colorado. This was done by moving the diversion point of the gas-fired power plant and the regional water supply for Farmington, Kirtland, and Aztec to Ridges Basin Reservoir. According to the model, the return flows of the Gas-Fired Power Plant will return to the mouth of the La Plata River and return flows of the Regional Water Supply will return to the Animas River below Basin Creek. The overall configuration of the model before modifications to ALP is shown in Figure 1. The configuration for the ALP Project modified for Colorado Ute Tribes and New Mexico depletions is included in Figure 2.

The model was applied by using the basic recommended Navajo Reservoir operating rules from the San Juan River Basin Recovery Implementation Program (SJRBRIP) Flow Recommendation Report (Holden 1999), as modified for the ALP Project Final Supplemental Environmental Impact Statement (FSEIS) (Reclamation, 2000).

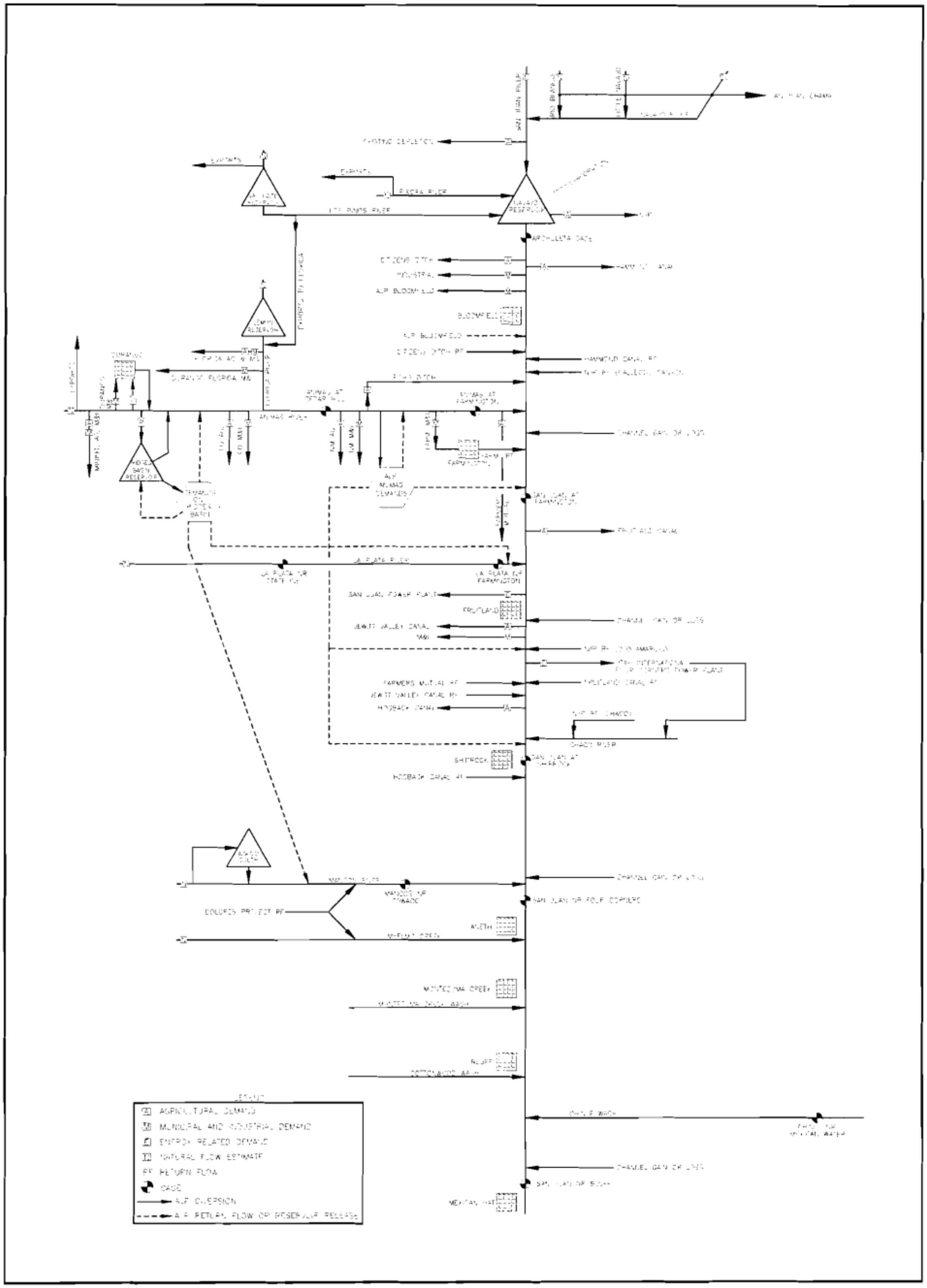

Figure 1.—Schematic of the San Juan River Basin as modeled.

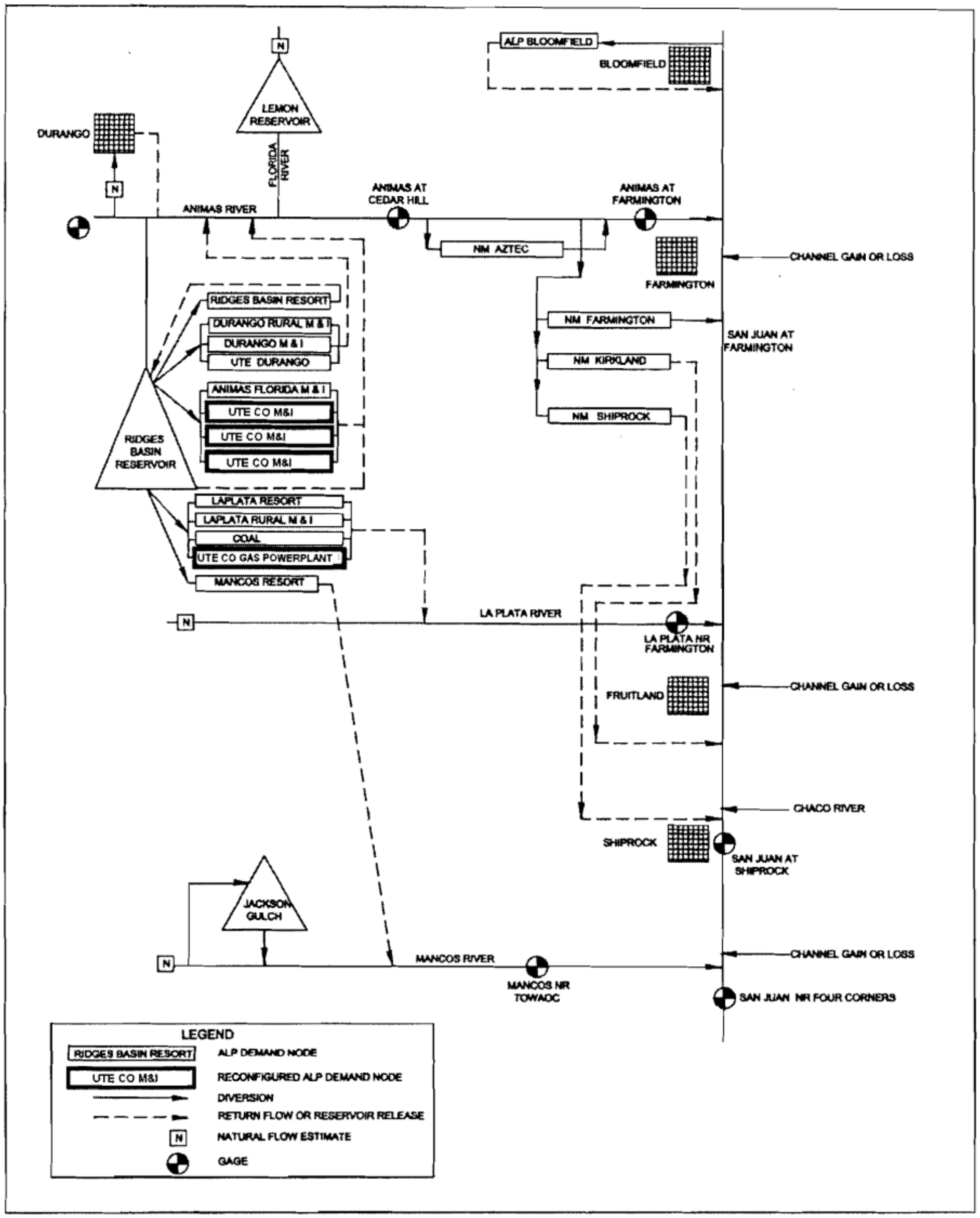

Figure 2.—Detail of the San Juan model to show components of ALP modified to eliminate interstate leasing or marketing of water.

Impact Analysis Results

No Action Analysis.—Since the foundation of impact determination is the future condition without implementing the flow recommendations, a model run for this level of depletion was completed. In all the following results, the comparison data listed as "No Action" come from this analysis. Detailed model output for the 1929-1993 modeling period appears in the **Modeled Output - No Action Alternative** at the end of this document.

250/5000 Alternative (Preferred Alternative).—Water resources under the Preferred Alternative are impacted two ways; first from changing the historical release patterns from Navajo Dam and secondly from allowing new depletions in the basin by meeting the criteria of the flow recommendations thereby reduce annual river flow volumes. On the San Juan River from Navajo Dam to the confluence of the Animas River, the main concern is minimum releases impacting the ability of existing diversion structures to divert their water rights. The impacts to the Animas River result more directly to the ALP than from changing release patterns of Navajo Dam. Impacts to the San Juan River from the Animas River confluence to Lake Powell are the result of implementing the flow recommendation operating criteria, and the effects of diversions and return flows of ALP and the completion of NIIP. Modeling has shown that the flow recommendations for endangered fish could be met and that existing water users and NIIP and the ALP Project would have an adequate water supply.

San Juan River at Archuleta Impacts.—Potentially adverse impacts could occur to existing diversion structures in the San Juan River from Navajo Dam to Farmington, New Mexico, as a result of reservoir operations that would reduce minimum releases from Navajo Dam to 250 cfs. A seven day Summer Low Flow Test (Test) was conducted July 9 to July 16, 2001, to evaluate the effects of low summer flows on various resources. The Test indicated that the water supply would not be a problem for most diverters, though inadequate facilities may have contributed to some shortages. Three diversions were adversely impacted during the test. (See diversion structures section in chapter III for more detail.) Table 2 summarizes San Juan River flows measured during the Test. The minimum flow was 63 cfs measured below the Hammond Diversion. Under actual conditions, flows could be higher or lower than flows measured during this Test.

Table 3 presents the mean, minimum and maximum monthly average flow at the San Juan River at Archuleta for the No Action, the Preferred Alternative, and the 500/5000 Alternative. The average annual impact is a reduction in flow of about 172,000 af for the Preferred Alternative. Flows are generally higher than those under the No Action Alternative during March through June and lower the rest of the time. Figures 3-5 are daily plots of typical dry, average and wet years that compare the No Action and Preferred Alternative. The stairstep nature of the hydrographs reflects the nature of reservoir releases remaining constant over certain time periods. Figure 6 is a frequency distribution of Navajo Dam releases comparing the three alternatives. It shows that under the Preferred Plan, monthly releases will be less than the No Action Alternative about 76 percent of the time. Detailed model output for the Preferred Plan appears in **Modeled Output - 250/5000 Alternative** at the end of this document.

Table 2.—Summary of streamflows measured during 2001 Summer Low Flow Test

Location	River mile	Flow (cfs)
San Juan River at Archuleta	218.5	267.9
San Juan River At Soaring Eagle Lodge	216.4	132.7
San Juan River Above Turley Inlet Channel	214.4	131.4
San Juan River Below Hammond Diversion	209.1	63.0
San Juan River Below Blanco Bridge	207.0	87.7
San Juan River Above Bloomfield Bridge	195.8	130.0
San Juan River Below Bloomfield Sewer effluent	194.8	131.1
San Juan River Below Lee Acre's Bridge	188.5	185.7
San Juan River 1/4 mile Above Animas River Confluence	181.4	218.7

Table 3.—Mean, maximum and minimum average flow of the San Juan River at Archuleta for the No Action, Preferred, and 500/5000 Alternatives (1929-1993 data)

	No Action			**250/5000**			**500/5000**		
	Average monthly flows (cfs)			Average monthly flows (cfs)			Average monthly flows (cfs)		
Month	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
October	984	3,791	500	388	1,010	250	501	957	0
November	1,015	3,126	500	321	1,554	250	507	1,189	0
December	978	1,782	500	360	1,617	250	544	1,780	0
January	887	1,290	500	296	433	250	486	500	0
February	500	500	500	287	444	250	488	500	0
March	606	4,929	500	672	5,000	250	715	4,250	500
April	1,144	5,000	500	1,260	5,000	250	1,063	4,750	500
May	1,323	5,000	500	2,195	5,000	250	1,795	5,000	500
June	1,798	5,000	500	2,215	3,937	250	1,660	3,749	500
July	1,022	4,590	500	386	1,476	250	538	1,454	227
August	898	3,465	500	471	1,104	250	531	1,081	0
September	1,004	4,339	500	459	1,027	250	517	1,004	0
Average	**1,013**	**3,568**	**500**	**776**	**2,300**	**250**	**779**	**2,184**	**186**
Maximum	**1,798**	**5,000**	**500**	**2,215**	**5,000**	**250**	**1,795**	**5,000**	**500**
Minimum	**500**	**500**	**500**	**287**	**433**	**250**	**486**	**500**	**0**

Note: Minimum flows of zero are shown under the 500/5000 Alternative because the reservoir is occasionally drawn down below the NIIP inlet works. In actuality, the reservoir inflows would be bypassed to meet downstream water uses.

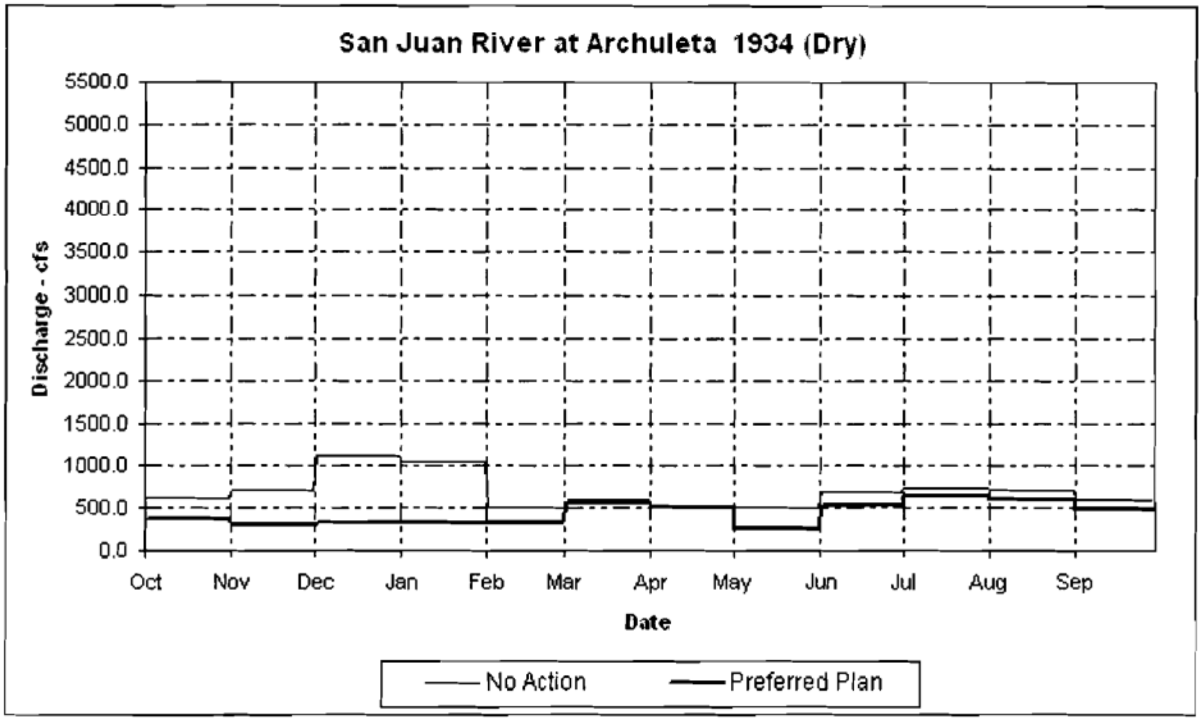

Figure 3.—Typical dry year hydrograph for San Juan River at Archuleta, New Mexico, USGS gage (same as Navajo Dam release) for the No Action Alternative compared to the Preferred Plan.

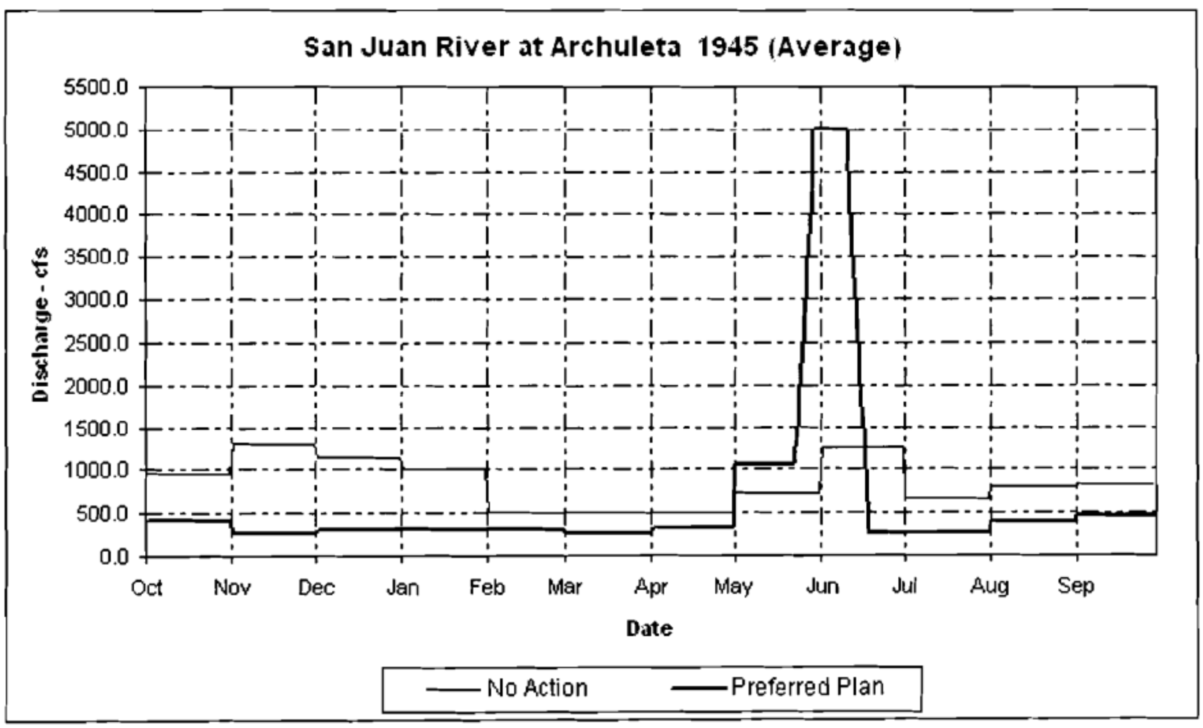

Figure 4.—Typical average year hydrograph for San Juan River at Archuleta, New Mexico, USGS gage (same as Navajo Dam release) for the No Action Alternative compared to the Preferred Plan.

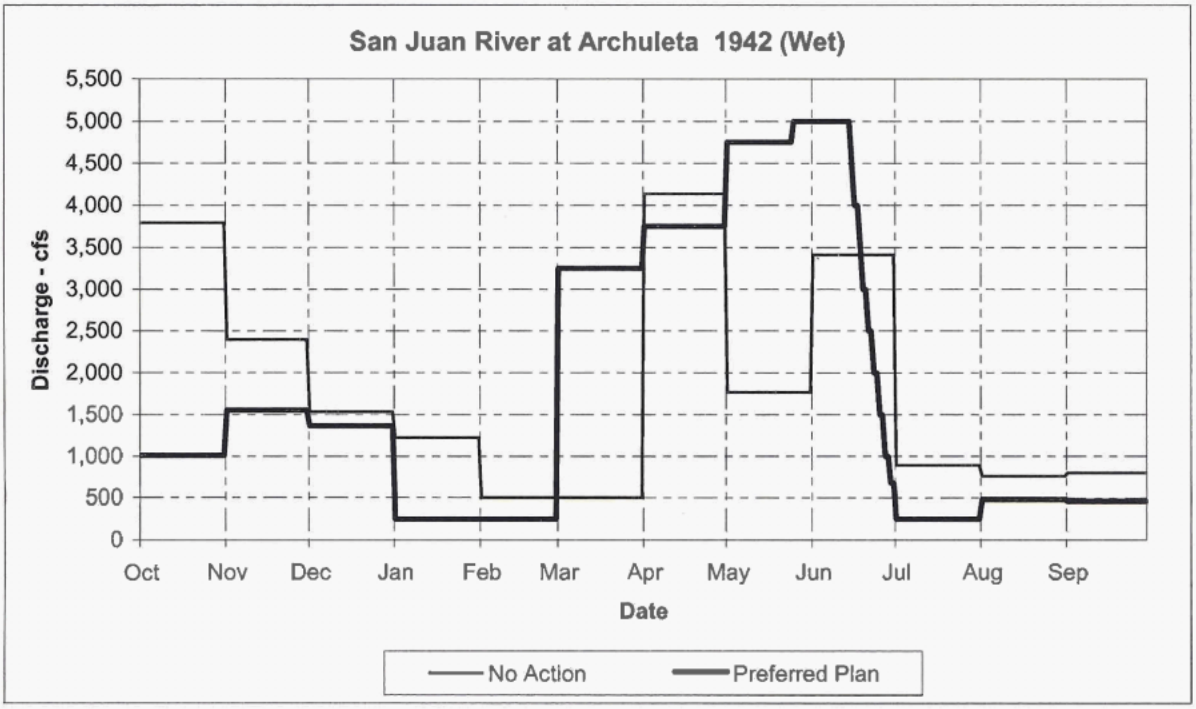

Figure 5.—Typical wet year daily hydrograph for San Juan River at Archuleta, New Mexico, (same as Navajo Dam release) for the No Action Alternative compared to the Preferred Plan.

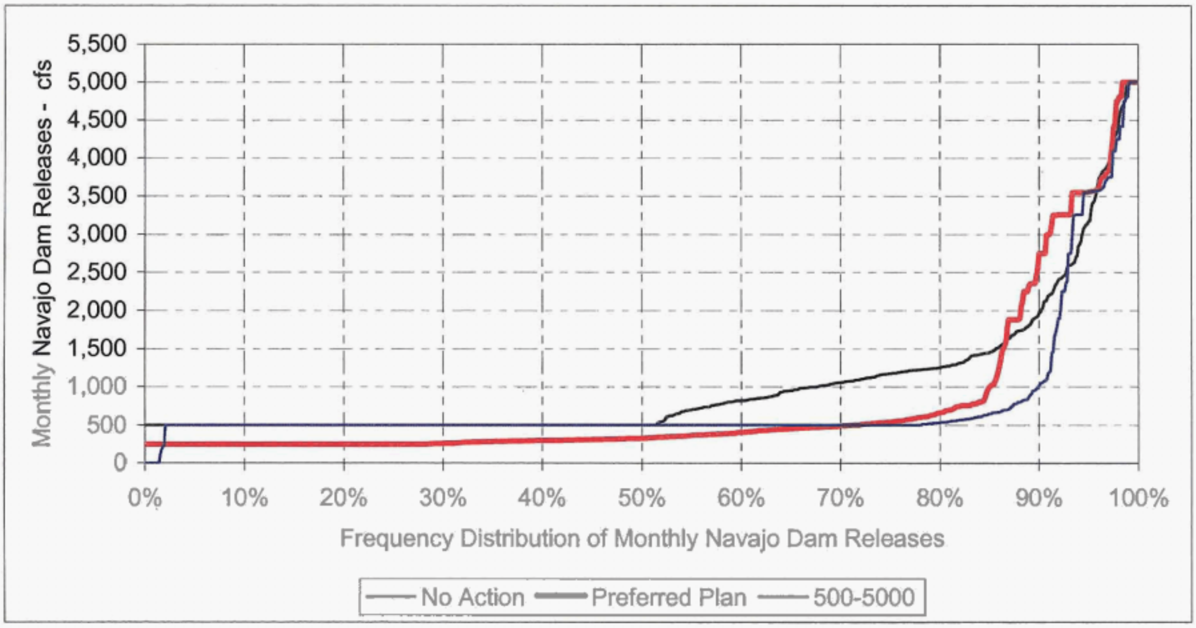

Figure 6.—Frequency distribution of Navajo Dam releases for the period 1929-1993 for the No Action, Preferred Plan, and 500/5000 Alternatives.

Animas River at Farmington Impacts

Operation of the ALP impacts the flows on the Animas River. At the confluence with the San Juan River, most of the diversions for the ALP have been taken and few of the project return flows are back. This is the location of maximum impact, with a mean annual reduction in flow of about 82,900 af. Table 4 presents the mean, minimum and maximum monthly average flow of the Animas River at Farmington for the No Action, Preferred, and 500/5000 Alternative. These flows are below the Farmer's Mutual ditch diversion just upstream of the confluence with the San Juan River. Under historic conditions, there ware shortages in the driest years, resulting in a model computed zero flow. In reality, some flow passes this point due to the inability to divert 100 percent of the water. With the project in place, there is a small enhancement in flows at this point.

The impacts to the Animas River are greatest during wet periods when there are no restrictions on the Durango Pumping Plant at Durango, although percentage impacts for the Animas River at the San Juan River confluence are greatest in moderately dry months. In the driest month, occurring during the irrigation season, there is no significant change in flows at the San Juan River confluence since the lowest diversion is typically water short in three dry periods and takes all the available water under either condition.

The above analysis is for average monthly flows. To demonstrate daily effects, the daily flows of the Animas River at Farmington were plotted for a typical dry, average and wet year for Preferred Alternative versus the No Action Alternative in Figures 7-9. Detailed model output for the Preferred Alternative appears in **Modeled Output - 250/5000 Alternative** at the end of this document.

Table 4.—Mean monthly flows for the Animas River at the confluence with the San Juan River for the No Action, Preferred, and 500/5000 Alternatives (1929-1993 data)

Month	No Action Average monthly flows (cfs)			Preferred Alternative Average monthly flows (cfs)			500/5000 Average monthly flows (cfs)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
October	400	2,675	92	279	2,550	67	279	2,550	67
November	350	1,165	191	277	1,073	179	277	1,073	179
December	275	566	178	233	539	156	234	539	156
January	240	384	116	213	353	115	214	357	115
February	251	451	129	213	392	130	214	392	130
March	432	1,010	131	352	933	129	353	933	129
April	952	2,497	36	788	2,245	33	790	2,245	33
May	2,190	4,961	221	1,993	4,799	78	1,998	4,808	78
June	2,738	5,902	44	2,514	5,903	51	2,501	5,623	51
July	955	3,399	0	784	3,119	10	785	3,119	10
August	344	1,570	0	219	1,382	9	218	1,382	9
September	318	1,749	0	210	1,588	7	210	1,588	7
Average	**787**	**2,194**	**95**	**673**	**2,073**	**80**	**673**	**2,051**	**80**
Maximum	**2,738**	**5,902**	**221**	**2,514**	**5,903**	**179**	**2,501**	**5,623**	**179**
Minimum	**240**	**384**	**0**	**210**	**353**	**7**	**210**	**357**	**7**

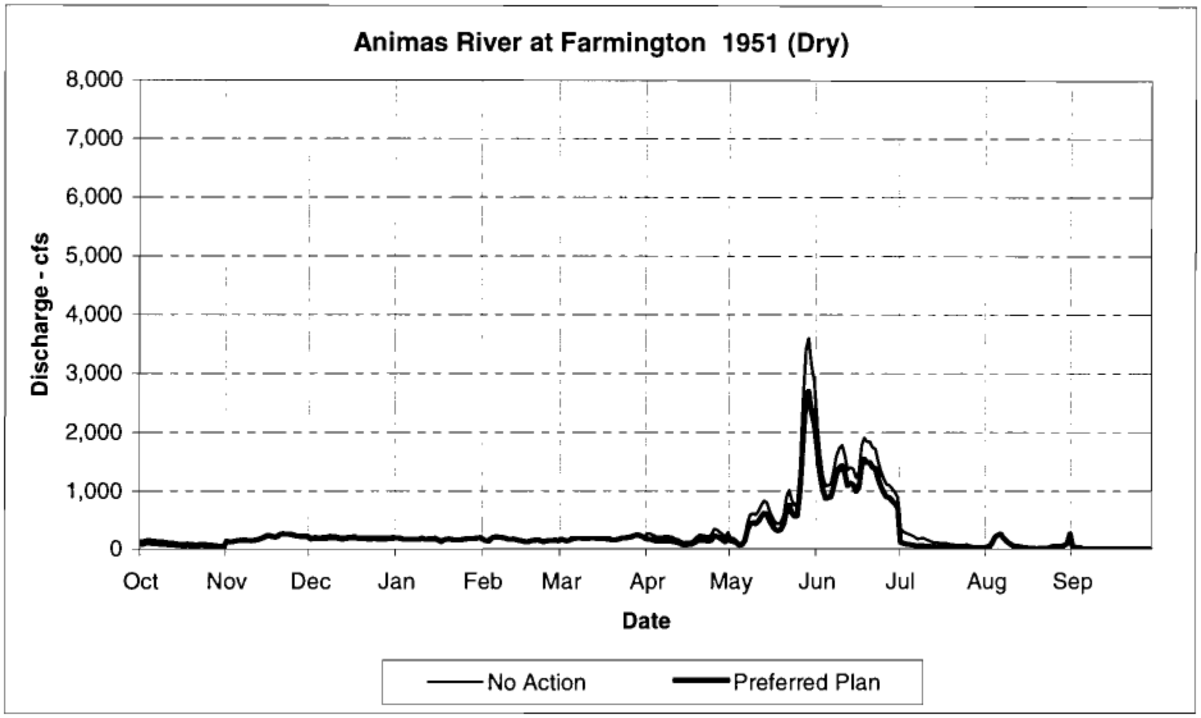

Figure 7.—Typical dry year daily hydrograph for the Animas River at the cnfluence with the San Juan River for the No Action Alternative compared to the Preferred Plan.

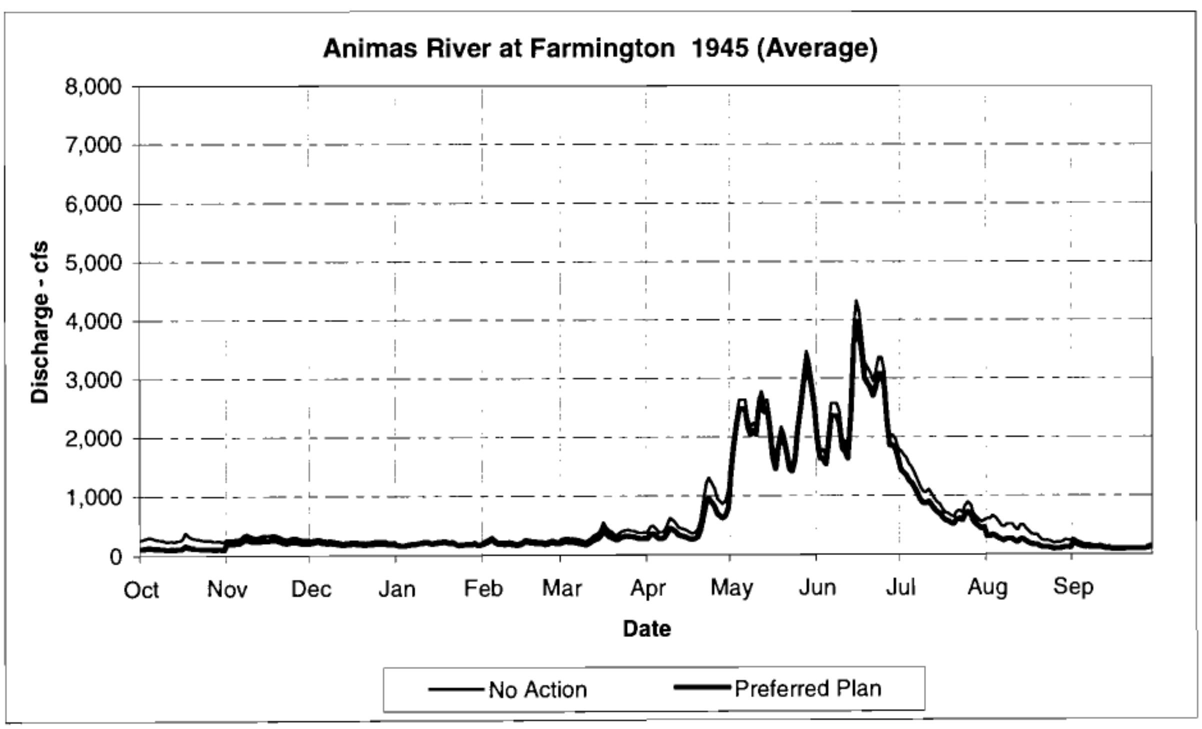

Figure 8.—Typical average year daily hydrograph for the Animas River at the confluence with the San Juan River for the No Action Alternative compared to the Preferred Plan.

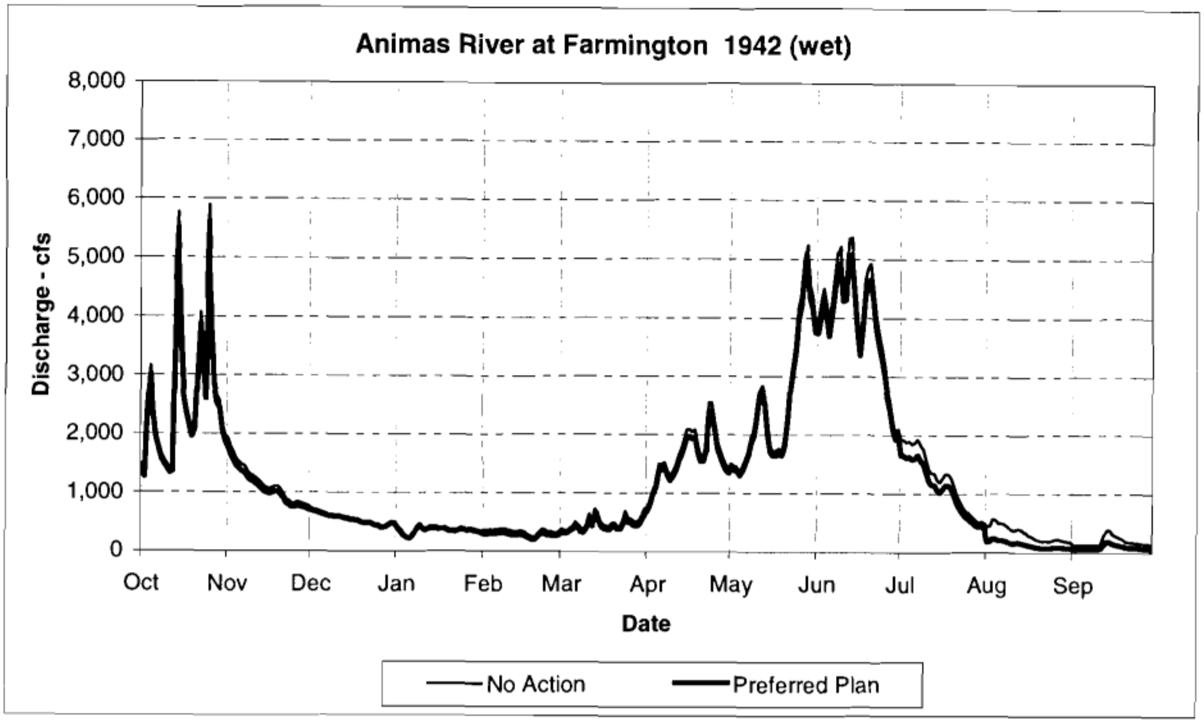

Figure 9.—Typical wet year daily hydrograph for the Animas River at the confluence with the San Juan River for the No Action Alternative compared to the Preferred Plan.

San Juan River At Farmington Impacts

Table 5 shows the mean, maximum and minimum monthly average flow at the San Juan River at Farmington for the No Action, Preferred, and the 500/5000 Alternative. The average annual effect on the San Juan River varies somewhat between the confluence with the Animas and Four Corners as return flow enters the system. The greatest impact, 251,100 acre-feet per year (afy), occurs between the confluence with the Animas and the confluence with the La Plata rivers. The minimum flow requirements for endangered fish are met. Mean monthly flows will be the same or slightly higher during March through June, while during the remainder of the time, mean monthly flows will be about 50 percent compared to the No Action Alternative. Generally, maximum monthly flows are similar during March through June, but again are about 50 percent of the No Action Alternative for the remainder of the time. April through September will see higher minimum flows than the No Action Alternative, but slightly lower minimums during the remainder of the time. As shown in the flow exceedence duration curve in Figure 10, flows under the No Action Alternative which are exceeded a given percentage of time would be changed under the Preferred Alternative as follows:

- 10 percent of the time - from 3,748 cfs to 4,131 cfs
- 50 percent of the time - from 1,230 cfs to 610 cfs
- 90 percent of the time - from 708 cfs to 525 cfs

To demonstrate daily effects, the daily flows of the San Juan River at Farmington were plotted for a typical dry, average and wet year for the Preferred Alternative compared to the No Action and 500/5000 Alternative in Figures 11-13. Detailed modeled output for the Preferred Alternative appears in **Modeled Output - 250/5000 Alternative** at the end of this document.

Table 5.—Mean monthly flows for the San Juan River at Farmington, New Mexico (USGS Gage) for the No Action, Preferred, and the 500/5000 Alternatives (1929-1993 data)

Month	No Action Average monthly flows (cfs)			250-5000 Average monthly flows (cfs)			500/5000 Average monthly flows (cfs)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
October	1,410	6,513	598	697	3,611	525	811	3,558	108
November	1,401	4,167	713	637	2,673	525	823	2,307	259
December	1,295	2,328	712	634	2,138	525	820	2,301	221
January	1,180	1,734	703	563	738	525	755	988	227
February	831	1,286	620	584	1,060	525	785	1,229	245
March	1,090	5,480	619	1,078	5,418	525	1,122	4,918	623
April	2,056	6,314	432	2,014	6,709	525	1,819	6,459	525
May	3,423	9,947	613	4,109	9,792	695	3,713	9,801	782
June	4,460	10,596	484	4,667	9,213	525	4,100	9,076	525
July	1,925	7,413	442	1,132	4,131	525	1,285	4,108	233
August	1,203	4,995	409	661	1,842	525	722	1,851	37
September	1,302	5,733	455	656	2,034	525	716	2,284	29
Average	**1,798**	**5,542**	**567**	**1,453**	**4,113**	**539**	**1,456**	**4,073**	**318**
Maximum	**4,460**	**10,596**	**713**	**4,667**	**9,792**	**695**	**4,100**	**9,801**	**782**
Minimum	**831**	**1,286**	**409**	**563**	**738**	**525**	**716**	**988**	**29**

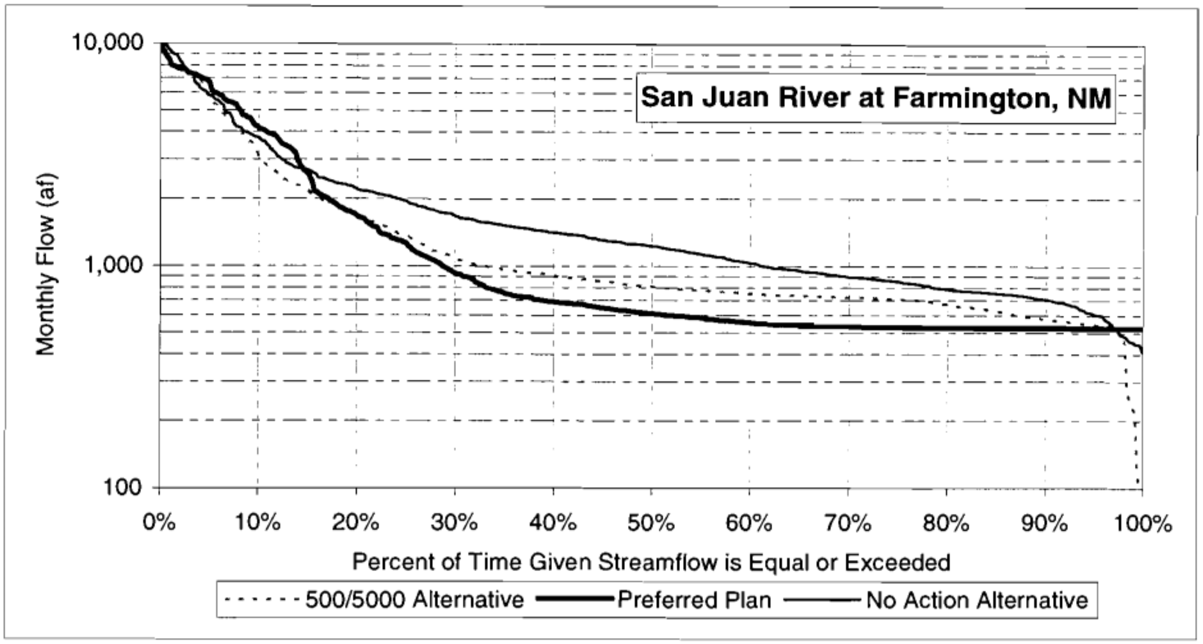

Figure 10.—Comparison of streamflow exceedence for the San Juan River at Farmington New Mexico, USGS gage, for the Preferred Plan, No Action, and 500/5000 Alternatives.

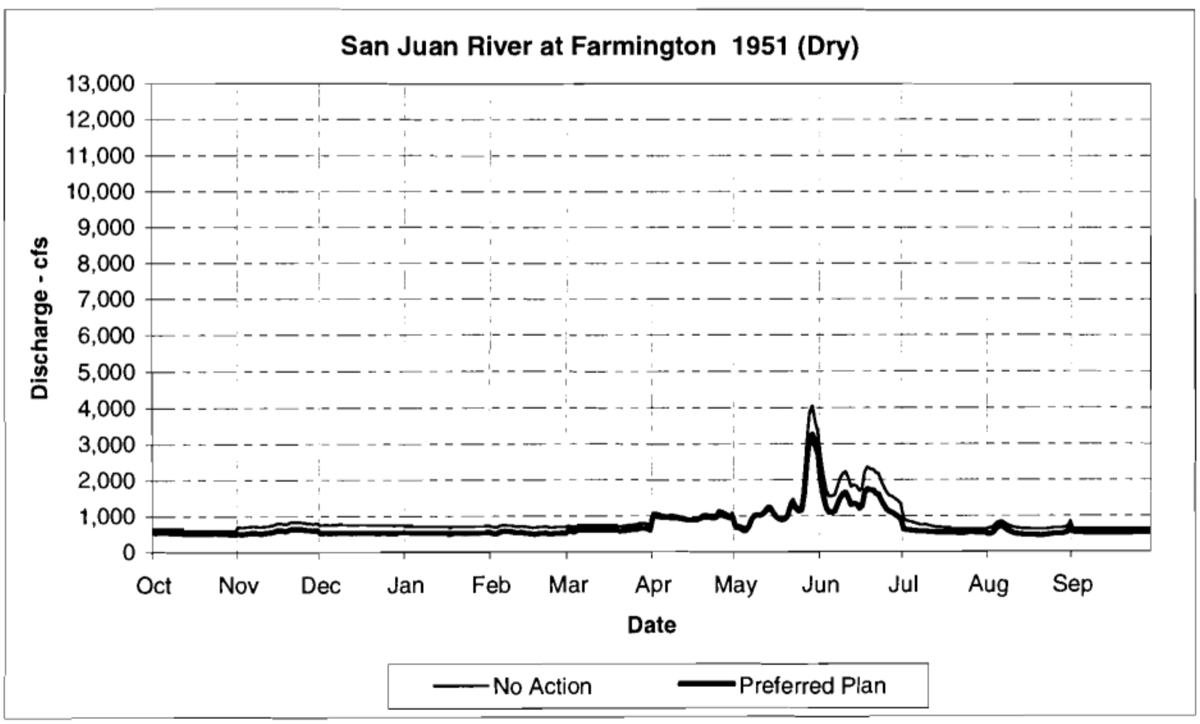

Figure 11.—Typical dry year daily hydrograph for the San Juan River at Farmington, New Mexico, for the Preferred Plan compared to the No Action Alternative.

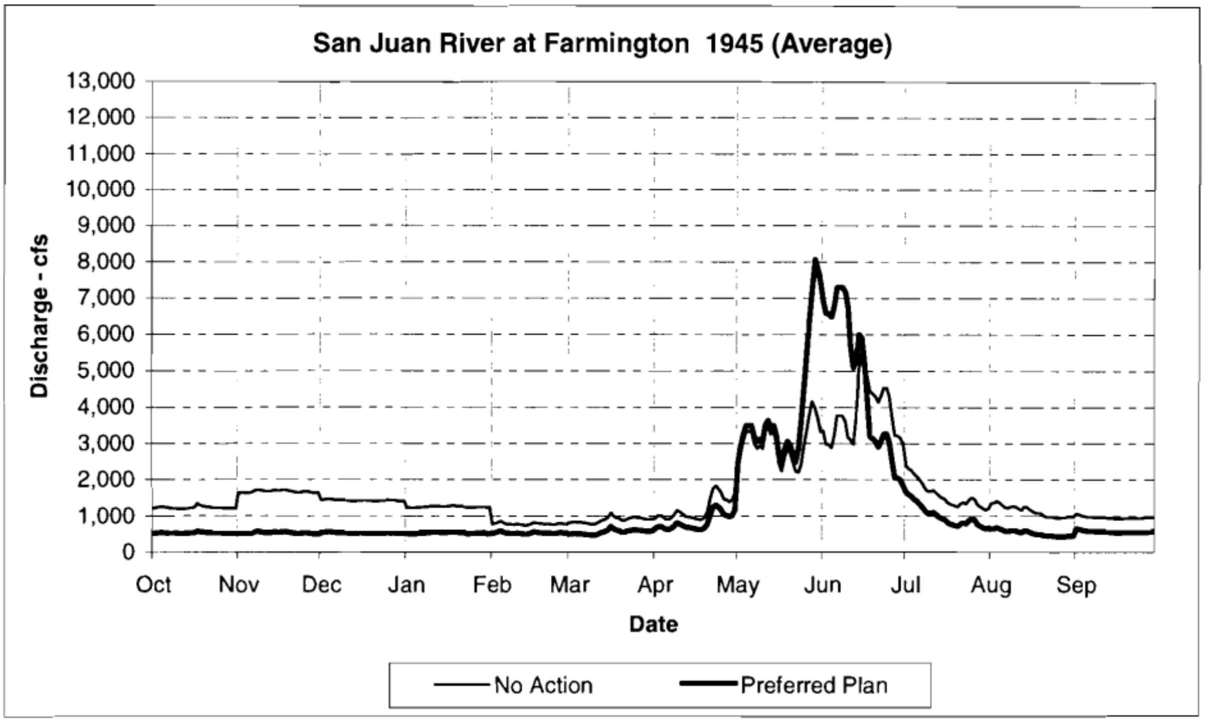

Figure 12.—Typical average year daily hydrograph for the San Juan River at Farmington, New Mexico, USGS gage, for the Preferred Plan compared to the No Action Alternative.

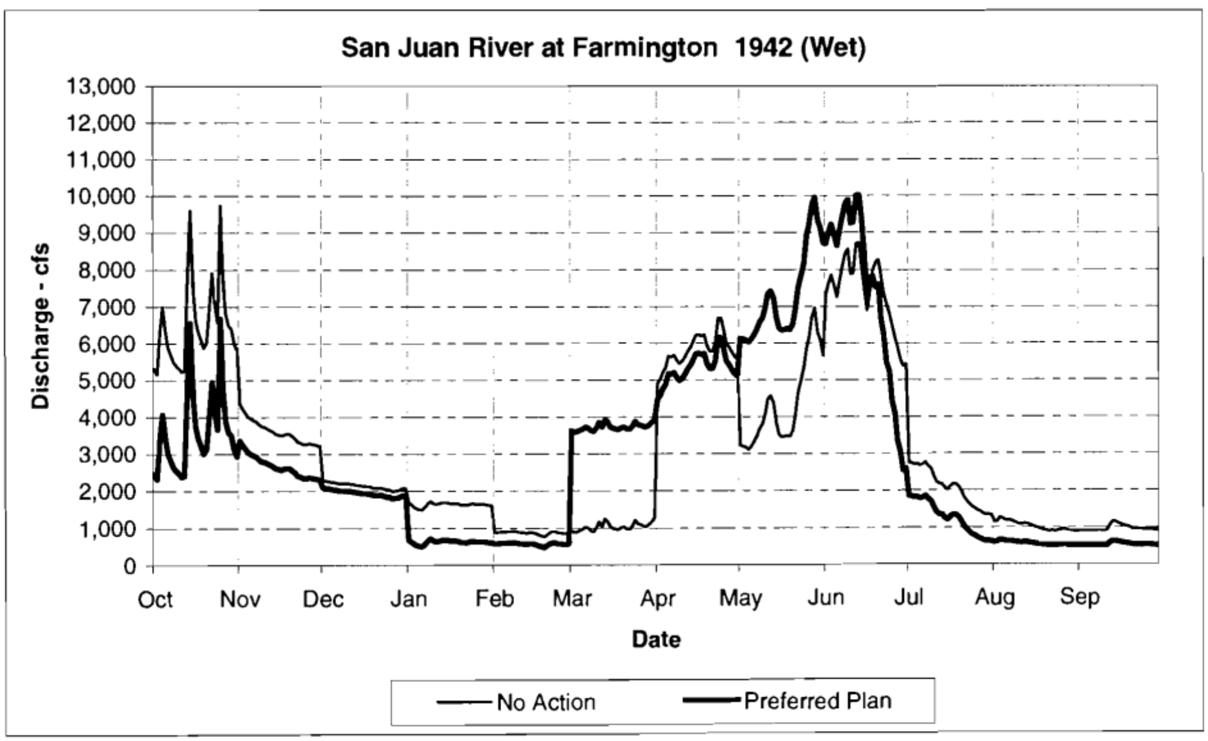

Figure 13.—Typical wet year daily hydrograph for the San Juan River at Farmington, New Mexico, USGS gage, for the Preferred Plan compared to the No Action Alternative.

San Juan River at Four Corners Impacts

The Four Corners gage has been the typical location for analyzing flows for endangered fish. Therefore, all impacts are analyzed at Four Corners, New Mexico.

At this point all return flows from the various components of ALP and NIIP are in the river. The net impact at this location is an average annual reduction of 195,500 af. The mean, maximum and minimum monthly average flows at this location over the 65-year modeling period appear in Table 6. Statistics are shown for the No Action, Preferred, and 500/5000 Alternative. Mean monthly flows will be the similar to the No Action Alternative during the spring runoff period of March through June; however, July through February will see mean monthly flows at between 30-50% less than the No Action Alternative. Minimum monthly flows are higher for 6 months and the same or slightly lower for the remaining 6 months. The target base flows of 500 cfs will help reduce the very low flows seen in the No Action Alternative. The change to maximum monthly flows occurs to the non-spring runoff periods when flows will be reduced as much as 50% of the No Action flows.

Table 7 is a comparison of the flow statistics for the No Action, Preferred, and the 500/5000 Alternative shown for the parameters specified in the flow recommendation report (Holden, 1999). The shaded areas indicate criteria category failure.

As shown in the monthly flow exceedence duration curve in Figure 14, flows under the No Action Alternative which are exceeded a given percentage of time would be changed under the Preferred Alternative as follows:

- 10 percent of the time - from 3,870 cfs to 4,334 cfs
- 50 percent of the time - from 1,303 cfs to 759 cfs
- 90 percent of the time - from 721 cfs to 548 cfs

To visualize the effect on the river on a daily basis, a typical dry, average and wet year was chosen and the daily average streamflow plotted for the No Action, Preferred, and 500/5000 Alternative. These plots appear in Figures 15-17. Detailed modeled output appears in **Modeled Output - 250/5000 Alternative** at the end of this document.

Table 6.—Mean monthly flows for the San Juan River at Four Corners, Colorado (USGS Gage) for the No Action, Preferred, and 500/5000 Alternatives (1929-1993 data)

Month	No Action Average monthly flows (cfs)			250-5000250/5000 Average monthly flows (cfs)			500/5000 Average monthly flows (cfs)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
October	1,559	9,029	480	903	6,178	525	1,018	6,124	62
November	1,447	4,272	660	723	3,087	525	910	2,721	240
December	1,339	2,490	716	702	2,329	525	888	2,492	232
January	1,232	2,015	705	639	1,041	525	830	1,291	305
February	980	2,255	661	766	2,011	525	967	2,233	435
March	1,172	5,966	527	1,198	5,918	525	1,241	5,168	600
April	2,140	6,888	362	2,162	7,339	589	1,966	7,089	589
May	3,404	12,208	577	4,190	12,137	738	3,793	12,146	819
June	4,467	10,701	802	4,830	9,469	800	4,263	9,332	956
July	2,040	7,776	408	1,402	4,654	631	1,555	4,632	560
August	1,407	7,128	226	995	4,080	540	1,056	4,088	299
September	1,428	7,357	251	879	3,428	538	940	3,436	56
Average	**1,885**	**6,507**	**531**	**1,616**	**5,139**	**582**	**1,619**	**5,063**	**429**
Maximum	**4,467**	**12,208**	**802**	**4,830**	**12,137**	**800**	**4,263**	**12,146**	**956**
Minimum	**980**	**2,015**	**226**	**639**	**1,041**	**525**	**830**	**1,291**	**56**

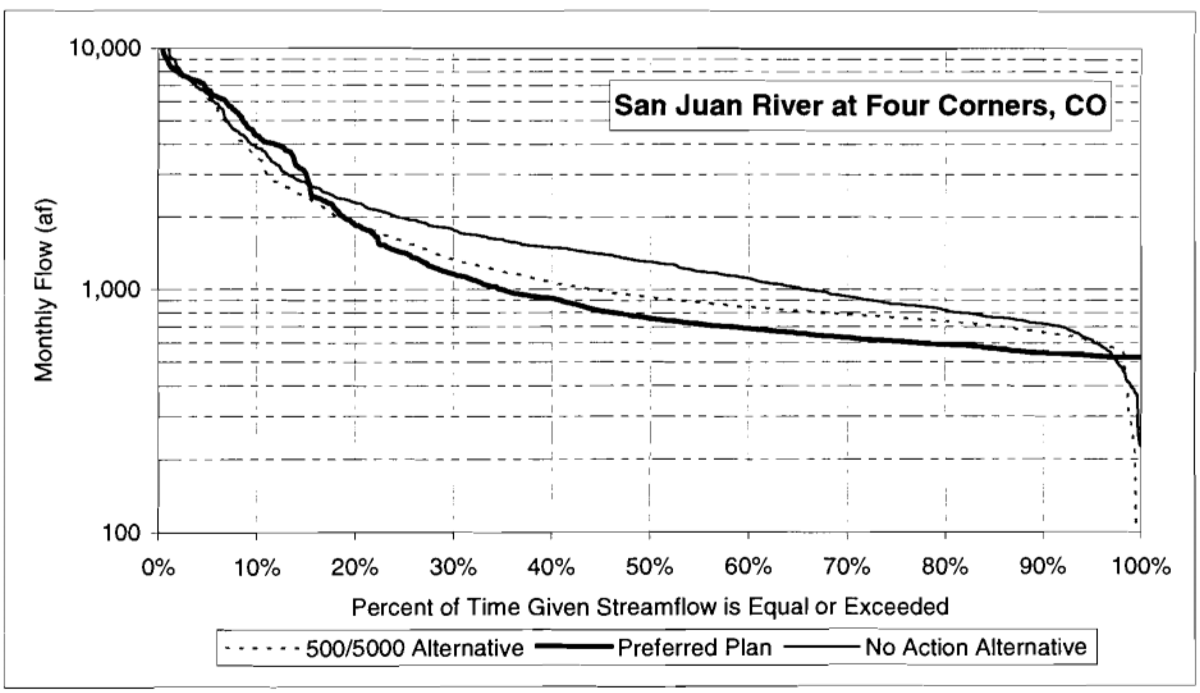

Figure 14.—Comparison of streamflow exceedence for the San Juan River at Four Corners, Colorado (USGS gage), for the Preferred Plan, No Action, and 500/5000 Alternatives.

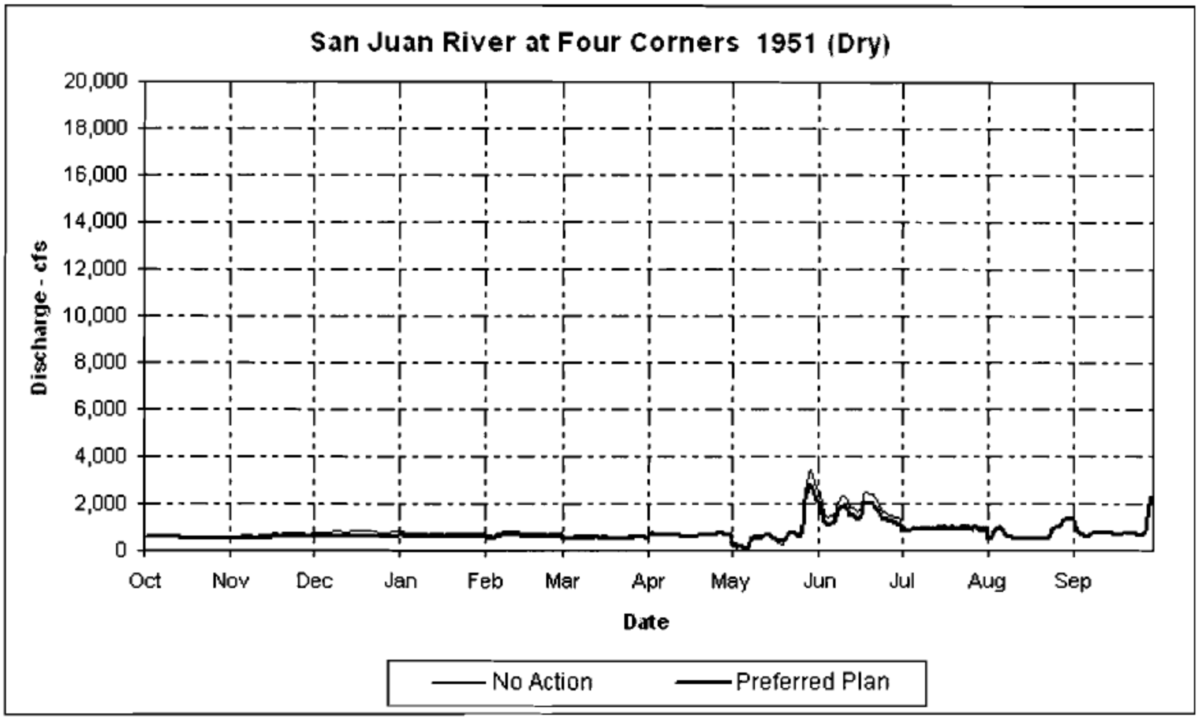

Figure 15.—Typical dry year daily hydrograph for the San Juan River at Four Corners for the Preferred Plan compared to the No Action Alternative.

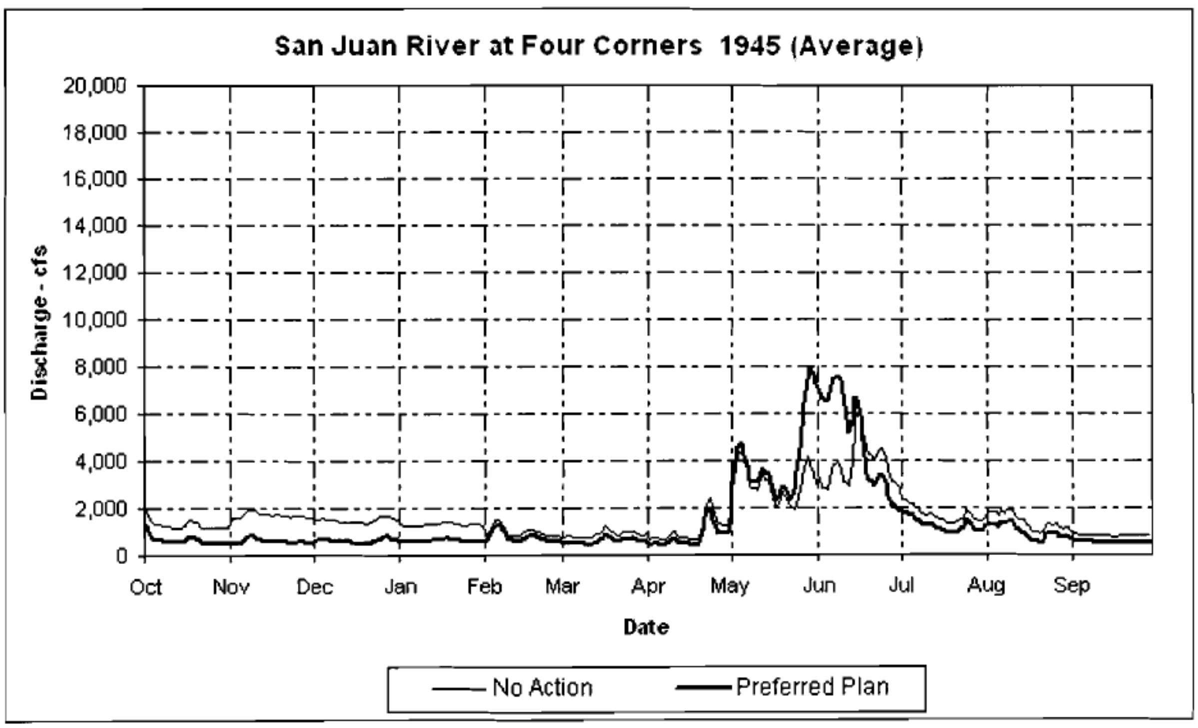

Figure 16.—Typical average year hydrograph for the San Juan River at Four Corners, Colorado, USGS gage, for the Preferred Plan compared to the No Action Alternative.

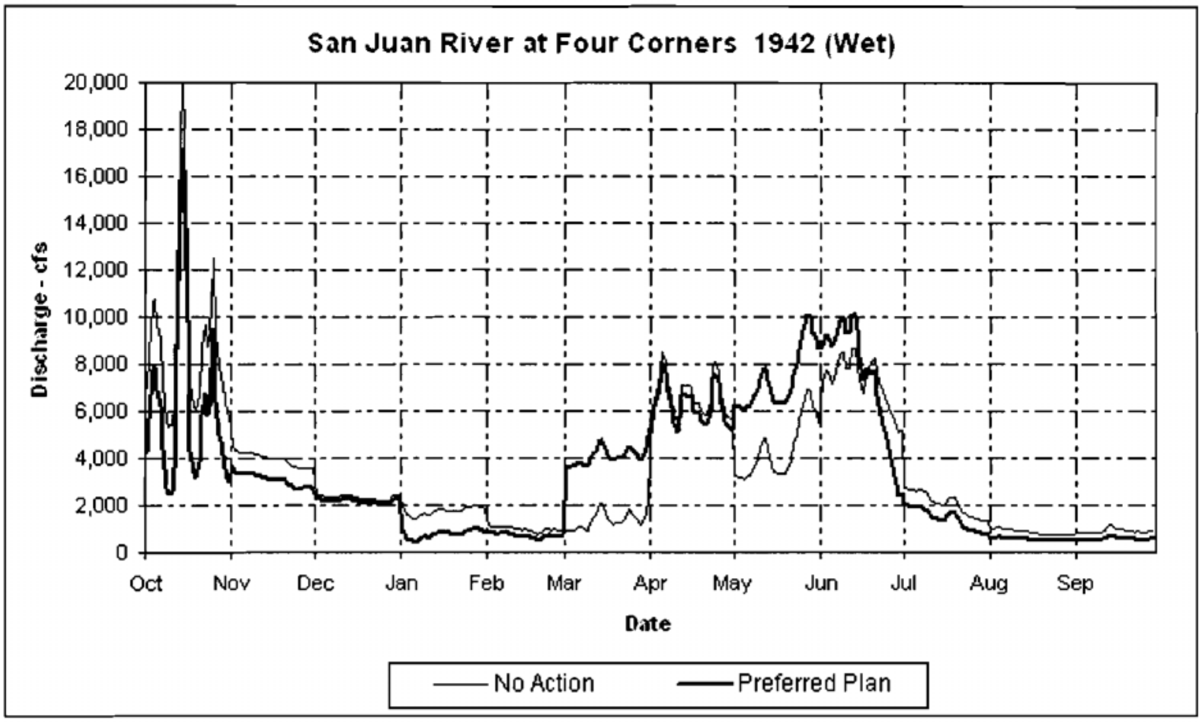

Figure 17.—Typical wet year daily hydrograph for the San Juan River at Four Corners, Colorado, USGS gage, for the Preferred Plan compared to the No Action Alternative.

Table 7.—Summary statistics of meeting Flow Recommendations criteria for alternatives retained for further analysis

	No Action Alternative				250/5000 Alternative				500/5000 Alternative			
	>10,000	>8,000	>5,000	>2,500	>10,000	>8,000	>5,000	>2,500	>10,000	>8,000	>5,000	>2,500
Duration	*Average frequency (percent)*				*Average frequency (percent)*				*Average frequency (percent)*			
1 day	**26.2**	**36.9**	**53.8**	100.0	33.8	56.9	73.8	95.4	**27.7**	43.1	**55.4**	96.9
5 days	**18.5**	**33.8**	**43.1**	90.8	27.7	47.7	69.2	86.2	21.5	35.4	**47.7**	86.2
10 days	**7.7**	**30.8**	**38.5**	81.5	15.4	38.5	66.2	81.5	13.8	**29.2**	**44.6**	80.0
15 days	**4.6**	**23.1**	**36.9**	72.3	7.7	30.8	56.9	75.4	6.2	**27.7**	**41.5**	72.3
20 days		13.8		69.2		24.6		72.3		**21.5**		66.2
21 days			**36.9**				53.8				**40.0**	
30 days		**7.7**	**35.4**	61.5		13.8	44.6	64.6		13.8	**33.8**	60.0
40 days			30.8	50.8			32.3	55.4			**27.7**	**49.2**
50 days			26.2	46.2			26.2	49.2			23.1	**40.0**
60 days			16.9	40.0			18.5	41.5			15.4	**33.8**
80 days			7.7	30.8			9.2	30.8			6.2	26.2

Maximum duration between events

Flow criteria - Max duration	Allowed	Modeled	Allowed	Modeled	Allowed	Modeled
9,700 cfs for 5 days - 10 years	10	**14**	10	10	10	**14**
7,760 cfs for 10 days - 6 years	6	**7**	6	6	6	**14**
4,850 cfs for 21 days - 4 years	4	**7**	4	4	4	**7**
2,450 cfs for 10 days - 2 years	2	2	2	2	2	2

Note: Shaded cells containing bolded numbers indicate failure to meet Flow Recommendations.

Flow recommendations flow/duration statistics				
	Discharge			
	>10,000	>8,000	>5,000	>2,500
Duration	*Average frequency (percent)*			
1 day	30.0	40.0	65.0	90.0
5 days	20.0	35.0	60.0	82.0
10 days	10.0	33.0	58.0	80.0
15 days	5.0	30.0	55.0	70.0
20 days		20.0		65.0
21 days			50.0	
30 days		10.0	40.0	60.0
40 days			30.0	50.0
50 days			20.0	45.0
60 days			15.0	40.0
80 days			5.0	25.0

Navajo Reservoir Water Level Impact from Operation of the Preferred Alternative

Operation of the Preferred Alternative implements the flow recommendations and the recommended reservoir operating rules (Holden, 1999). Releases from Navajo Dam are made to the river and to NIIP via the Navajo Dam Diversion Works. Impacts to water levels will be the result of changing historic release patterns to the river and increased diversions to NIIP as that project is completed. Under the Preferred Alternative, annual releases to the river will average 562,500 af compared to 735,000 af with the No Action Alternative, while diversions to NIIP will average 337,500 af compared to 166,250 af. Reservoir content will average 1,331,100 with the Preferred Alternative, compared to 1,410,700 af with the No Action Alternative. Table 8 displays the summary statistics for Navajo Reservoir monthly mean, median, maximum and minimum content and pool elevation for each alternative. Figure 18 shows this table graphically.

Figures 19 depicts the end-of-month storage for the 1929-1993 simulations for the Preferred Alternative compared to the historical contents. Figure 20 shows the end-of-month storage for the 1929-1993 simulations for the No Actions Alternative compared to the historical contents. Figure 21 shows the percent of time a given storage volume is equaled or exceeded and Figure 22 shows the percent of time a give pool elevation is equaled or exceeded.

Table 8.—Summary statistics 1929-1993 water years

Month	Navajo Reservoir storage			Navajo Reservoir pool elevation		
	No Action (acre-feet)	250-5000 (acre-feet)	500-5000 (acre-feet)	No Action (feet)	250-5000 (feet)	500-5000 (feet)
	Average monthly					
Jan	1,305,931	1,302,750	1,206,604	6,056.4	6,054.9	6,046.2
Feb	1,298,798	1,307,444	1,200,106	6,055.8	6,055.2	6,045.6
Mar	1,326,129	1,331,496	1,221,656	6,058.0	6,057.2	6,047.5
Apr	1,394,209	1,386,414	1,288,460	6,063.3	6,061.7	6,053.3
May	1,489,552	1,398,044	1,324,909	6,070.3	6,063.1	6,056.8
Jun	1,539,101	1,384,764	1,344,763	6,073.8	6,062.3	6,058.6
Jul	1,509,569	1,351,072	1,301,858	6,071.6	6,059.5	6,054.9
Aug	1,477,820	1,311,210	1,258,421	6,069.4	6,056.1	6,051.1
Sep	1,443,696	1,291,106	1,235,376	6,066.9	6,054.3	6,049.0
Oct	1,415,006	1,296,296	1,234,158	6,064.8	6,054.5	6,048.7
Nov	1,383,338	1,305,894	1,232,735	6,062.4	6,055.2	6,048.5
Dec	1,345,677	1,306,230	1,221,742	6,059.5	6,055.2	6,047.5

Table 8.—Summary statistics 1929-1993 water years (continued)

Month	Navajo Reservoir storage			Navajo Reservoir pool elevation		
	No Action (acre-feet)	250-5000 (acre-feet)	500-5000 (acre-feet)	No Action (feet)	250-5000 (feet)	500-5000 (feet)
Median monthly						
Jan	1,351,300	1,298,954	1,239,592	6,060.3	6,056.1	6,051.2
Feb	1,337,997	1,312,040	1,225,831	6,059.2	6,057.2	6,050.0
Mar	1,351,822	1,362,698	1,241,346	6,060.3	6,061.2	6,051.3
Apr	1,419,718	1,430,337	1,289,755	6,065.5	6,066.3	6,055.4
May	1,536,542	1,424,431	1,362,841	6,074.0	6,065.9	6,061.2
Jun	1,603,366	1,396,426	1,388,923	6,078.6	6,063.8	6,063.2
Jul	1,597,799	1,353,019	1,371,918	6,078.2	6,060.4	6,061.9
Aug	1,544,012	1,315,088	1,331,142	6,074.5	6,057.4	6,058.7
Sep	1,509,254	1,314,565	1,283,414	6,072.0	6,057.4	6,054.8
Oct	1,485,350	1,307,310	1,267,024	6,070.4	6,056.8	6,053.5
Nov	1,451,300	1,315,898	1,273,704	6,067.9	6,057.5	6,054.0
Dec	1,401,300	1,313,341	1,259,745	6,064.1	6,057.3	6,052.9
Maximum monthly						
Jan	1,351,300	1,673,555	1,598,208	6,060.3	6,083.2	6,078.2
Feb	1,376,158	1,701,300	1,622,861	6,062.2	6,085.0	6,079.9
Mar	1,451,300	1,696,097	1,662,711	6,067.9	6,084.7	6,082.5
Apr	1,501,300	1,701,300	1,684,343	6,071.5	6,085.0	6,083.9
May	1,624,321	1,685,719	1,668,165	6,080.0	6,084.0	6,082.9
Jun	1,691,238	1,650,570	1,634,405	6,084.4	6,081.7	6,080.6
Jul	1,626,300	1,643,529	1,588,844	6,080.1	6,081.2	6,077.6
Aug	1,626,300	1,605,204	1,560,059	6,080.1	6,078.7	6,075.6
Sep	1,551,300	1,685,639	1,616,326	6,075.0	6,084.0	6,079.4
Oct	1,501,300	1,701,300	1,657,539	6,071.5	6,085.0	6,082.2
Nov	1,451,300	1,701,300	1,662,147	6,067.9	6,085.0	6,082.5
Dec	1,401,300	1,661,300	1,601,300	6,064.1	6,082.4	6,078.4
Minimum monthly						
Jan	971,559	634,209	586,464	6,026.3	5,986.2	5,979.3
Feb	971,230	645,875	613,996	6,026.2	5,987.8	5,983.3
Mar	984,257	675,143	627,938	6,027.6	5,991.8	5,985.3
Apr	1,062,781	765,048	657,587	6,035.3	6,003.2	5,989.4
May	1,177,714	891,698	700,954	6,045.9	6,017.8	5,995.2
Jun	1,201,805	946,296	688,790	6,048.0	6,023.7	5,993.6
Jul	1,159,292	863,771	625,675	6,044.2	6,014.7	5,985.0
Aug	1,116,025	775,098	574,551	6,040.3	6,004.5	5,977.5
Sep	1,068,082	696,439	560,443	6,035.8	5,994.6	5,975.3
Oct	1,036,289	662,747	560,067	6,032.7	5,990.1	5,975.2
Nov	1,015,047	654,965	568,310	6,030.6	5,989.1	5,976.5
Dec	990,739	641,566	574,829	6,028.2	5,987.2	5,977.5

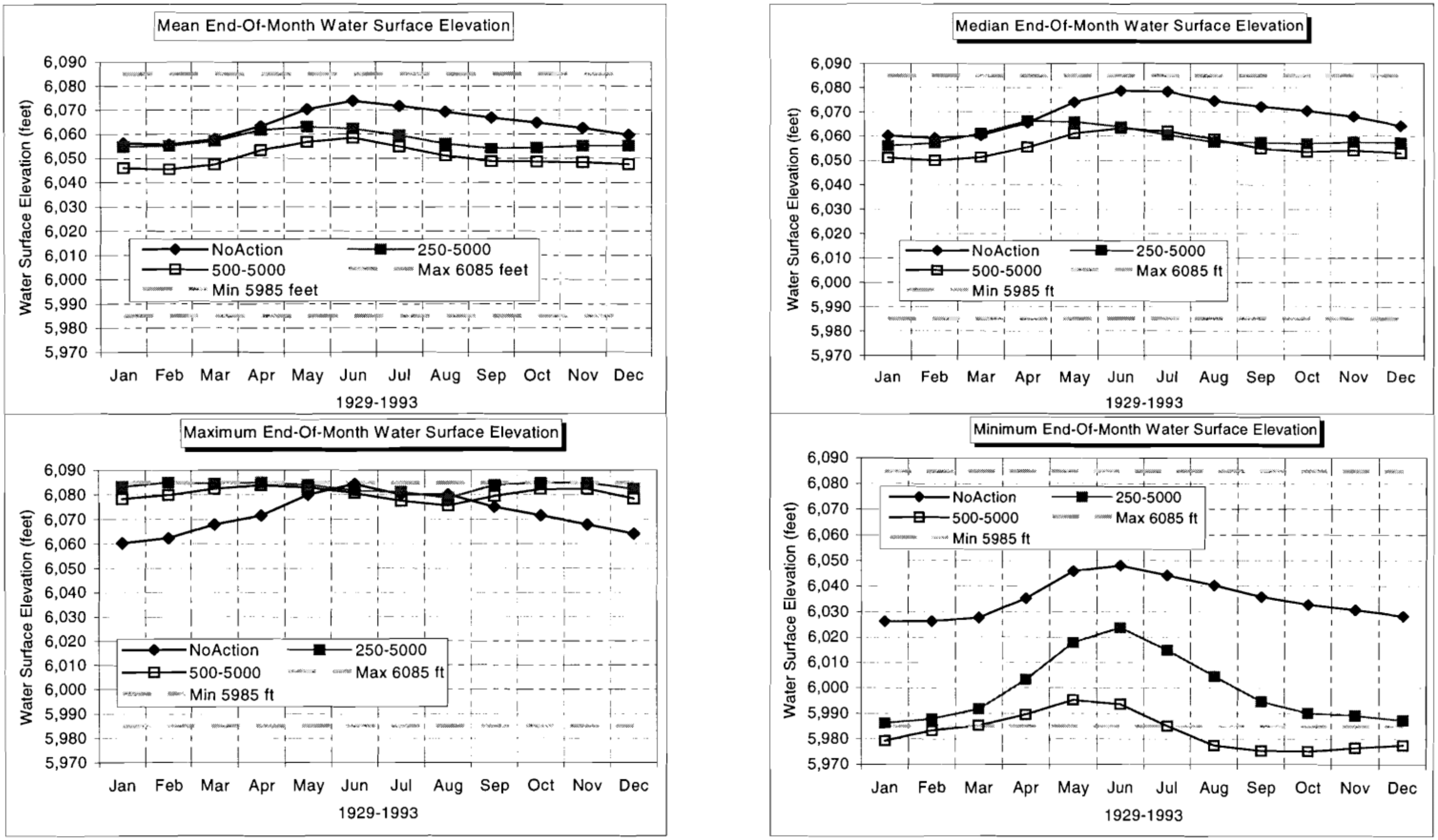

Figure 18.—Summary statistics of Navajo Reservoir end-of-month water surface elevation comparing each alternative.

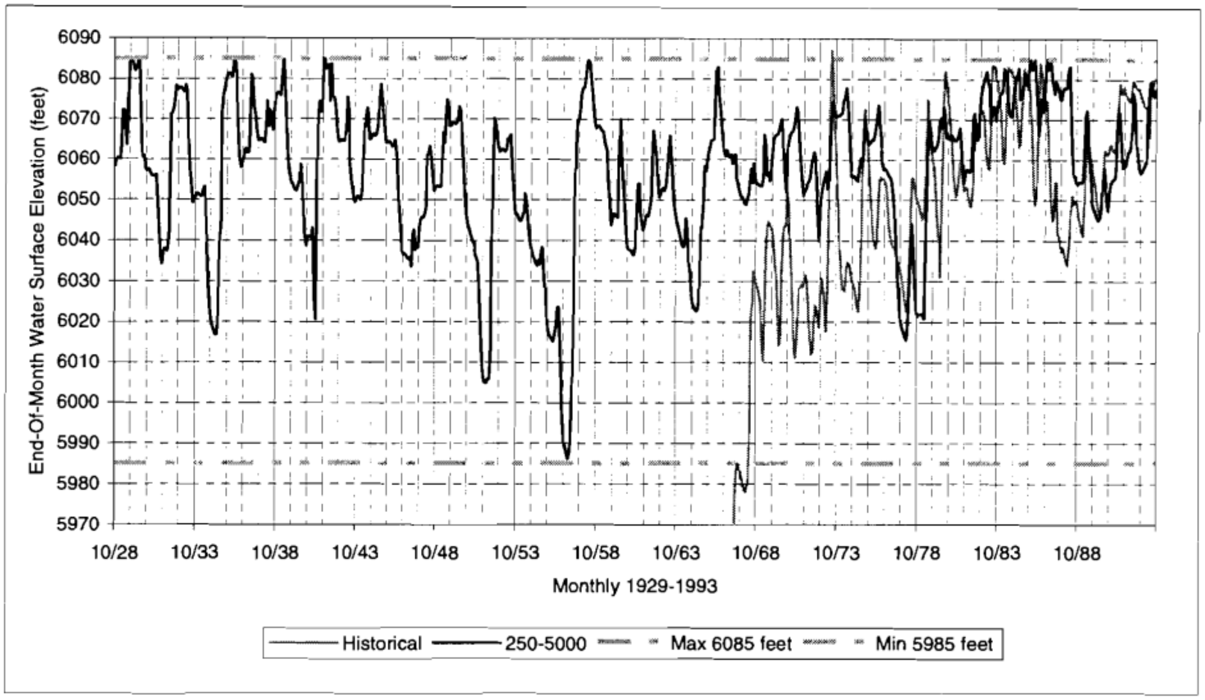

Figure 19.—Navajo Reservoir end-of-month water surface elevation comparing the Preferred Plan to the Historical.

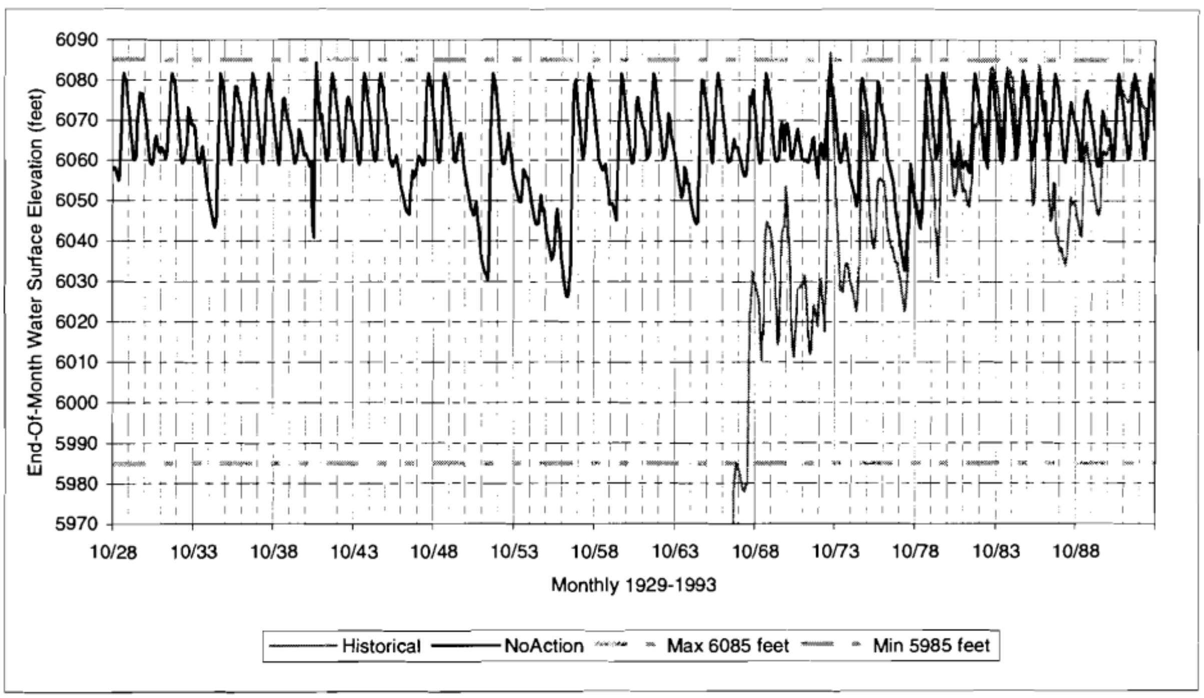

Figure 20.—Navajo Reservoir end-of-month water surface elevation comparing the No Action Alternative to the Historical.

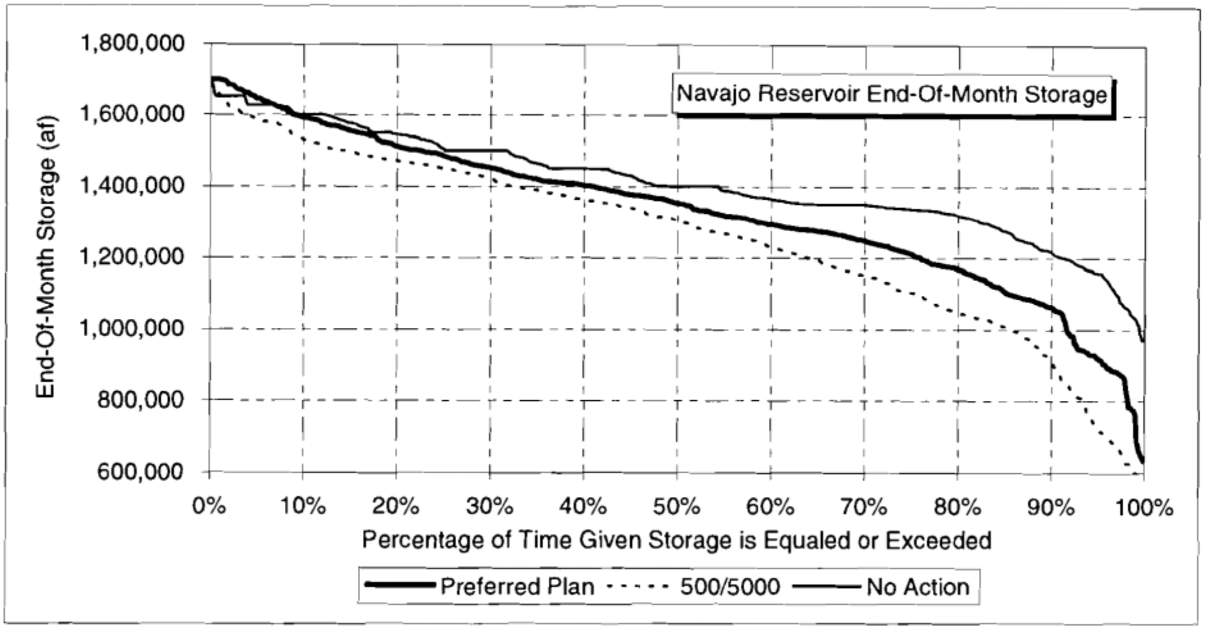

Figure 21.—Probability of given storage being equaled or exceeded in Navajo Reservoir comparing the Preferred Plan to the No Action and 500/5000 Alternatives.

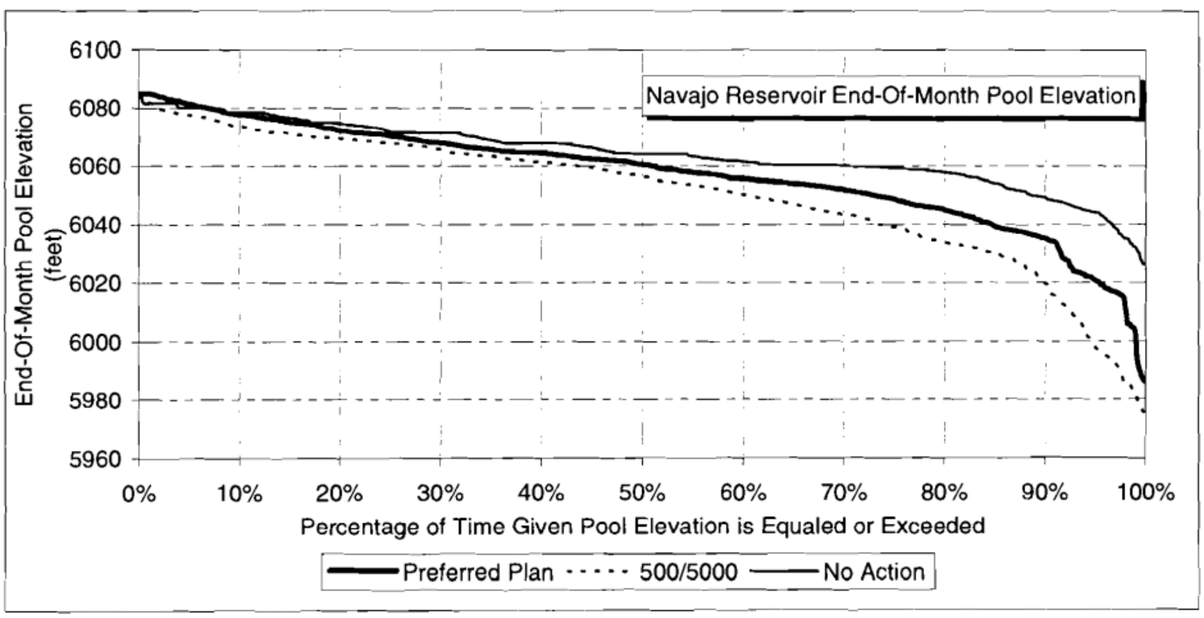

Figure 22.—Probability of given elevation being equaled or exceeded in Navajo Reservoir comparing the Preferred Plan to the No Action and 500/5000 Alternatives.