RECLAMATION

Managing Water in the West

DRAFT ENVIRONMENTAL IMPACT STATEMENT

ASPINALL UNIT OPERATIONS

ASPINALL UNIT—COLORADO RIVER STORAGE PROJECT
GUNNISON RIVER, COLORADO

VOLUME II
Technical Appendices

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region
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Appendix A

Aspinall Hydrology Report

ASPINALL EIS HYDROLOGIC REPORT

Introduction

Riverware was the simulation software selected by Reclamation for use in the development of a hydrology model to be used to evaluate alternatives. The model was originally developed by Reclamation in support of assessing the effects of the Black Canyon Water Right on the Aspinall Unit. It has been significantly improved and serves as a tool to analyze effects of the proposed alternatives. This model was developed solely for this purpose and Reclamation does not expect the model to be used as an operations model.

Modeling Scope

For this EIS, three basic model configurations were developed to simulate future conditions: the No Action Alternative; Risk of Spill Alternative; and the Peak Release Alternative. The Risk of Spill and Peak Release Alternatives were modified to include base flows and duration flows to evaluate their ability to better meet the Flow Recommendations. This appendix details the analysis process for determining impacts to hydrology from operation of the No Action Alternative, Alternative A (Risk of Spill), Alternative B (Fish Peaks with Minimum Duration), Alternative C (Fish Peaks with Extended Duration) and Alternative D (Fish Peaks – Fixed Targets). The results of this modeling effort are also presented.

In order to properly evaluate the effects of different reservoir operation scenarios, a hydrologic model was developed using the Riverware modeling program to simulate the operations of the Aspinall Unit under varying hydrologic conditions. The Gunnison River model was developed for the purpose of characterizing the hydrologic effects on the Aspinall Unit and the Gunnison River below the Aspinall Unit caused by the implementation of the proposed alternatives for the Aspinall Unit EIS. Four alternatives have been proposed for the Aspinall Unit EIS. The Action Alternatives modify operations of the three Aspinall Unit reservoirs with the goal of achieving the flow recommendations described in the *Flow Recommendations to Benefit Endangered Fishes in the Colorado and Gunnison Rivers* (2003 Flow Recommendations). The No Action Alternative continues current operations of the Aspinall Unit with occasional attempts to generate a spring peak based on reservoir inflow that is surplus to the volume needed to fill the reservoir and optimize hydropower production. Attempts to “bundle” this surplus water into a spring peak have been occurring since 1992. For each of the action alternatives, rules to operate the Aspinall Unit to achieve the flow targets described in the 2003 Flow Recommendations were developed. Rulesets were modified in each alternative with the goal of minimizing impacts to authorized purposes while still achieving the targets described in the Flow Recommendations. The purpose of this report is to summarize the hydrologic effects observed in the model output as a result of attempting to meet the Flow Recommendation targets for each of the alternatives. The results in this report focus on the model output from the Aspinall Unit and the Gunnison River below the Aspinall Unit.

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 four different controllers: simulation, rulebased simulation, water ownership, and optimization. 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 visible depend on the methods 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), (6) San Juan River Model for the San Juan basin (rules model with monthly and pseudo daily time-step) and (7) Gunnison River Basin Model (rules model with 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), and (2**)** Yakima River Basin Models (rules model with both monthly and daily time-steps)

Riverware Model of Gunnison 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 historic stream flows. **Outflows** consist of water flowing across the downstream basin boundary (Gunnison River at the confluence with the Colorado River at Grand Junction), diversions (Gunnison Tunnel and Redlands Power Canal), and consumptive use (crops, M&I, natural vegetation, free water surface evaporation, etc.). **Water storage** consists of the water within basin reservoirs. In the Gunnison River model only unnatural (man-induced) hydrologic effects are explicitly modeled.

The current Gunnison River model was developed through modification of a model originally created to support the assessment of the effects of the Black Canyon Water Right on the Aspinall Unit. To evaluate how well each run of the modeled alternatives achieved the flow objectives described in the Flow Recommendations, the Gunnison River model produces output at a daily timestep. From this daily output, numerous parameters can be evaluated including reservoir content, water volumes through the powerplants, days of powerplant bypasses and spills, peak flows at various points in the river as well as days above a target flow threshold.

The Gunnison River model simulates historic hydrology from 1975 to 2005. This period of record was selected as the most complete historical dataset at the time model analysis began and it is adequately representative of the past hydrological conditions of the basin containing both the driest and wettest periods for which data is available. Statistical analysis conducted by Reclamation (Cutler and Harpman 2005) compared 1906-2005, 1937-1997, and 1975-2005 periods of record and concluded that there is “no basis for presuming the 3 periods of record are statistically different”. In addition, selection of a period of record containing years prior to 1975 would require significant data synthesis as

daily records are incomplete in these earlier years. The initial conditions of the Gunnison River model were selected to be the state of the Aspinall Unit and Gunnison River system at the start of January of 1975. The Gunnison River model runs for the 31 year period between 1975 and 2005. The model runs a single trace of 31 years during this time period. This is adequate for this analysis because the ratio of average annual inflow to live storage for Blue Mesa Reservoir is so large. Flaming Gorge and Glen Canyon's EIS's both used iterative trace methods of analysis, however their ratio of inflow to live storage is in the 40% range. Blue Mesa's ratio of average inflow to active storage is nearly 100% which means an average year's runoff into Blue Mesa is about equal to the reservoir's active storage capacity. Consequently, if managed properly, the reservoir can easily "re-set" itself in a "less-than-average" year. This model was developed and used as a comparative tool to determine the relative performance of the alternatives, not to establish absolute operational flow rates or targets. In addition, it will not be used as an operation model in the future.

The Gunnison River model routes historic flows (as measured and recorded in the historical record), that enter the river system as inflows to Blue Mesa Reservoir, side inflows to Morrow Point and Crystal Reservoir, and flows in the Uncompahgre River as measured at the Uncompahgre River at Delta river gage. Tributary flows between Crystal Reservoir and Delta and between Delta and Whitewater are developed from computed historical gains and losses between the river gages at these points. Historical diversions to the Gunnison Tunnel and the Redlands Canal are used for the diversion points in the model. Using historical data eliminates the need to model natural hydrologic processes such as rainfall/runoff. Thus, precipitation falling on natural vegetation, consumptive use by natural vegetation, runoff of excess precipitation, evaporation from the free water surfaces of rivers, etc. is assumed to be reflected in the inflows. Therefore reach gains and losses are 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.

Outflows from the model consist of the routed flow of the Gunnison River at the confluence with the Colorado River, depletions including consumptive irrigation (irrigated crop evapotranspiration less effective precipitation), M&I use, and net (in excess of natural) evaporation from manmade reservoirs. The change in storage is reflected in the difference between beginning and ending reservoir content. The effects of soil water storage for irrigated lands are incorporated into the historical streamflow and stream reach gains and losses are not explicitly modeled.

All major elements of the Gunnison River system from the Aspinall Unit to the reach of the Gunnison River below the Redlands Diversion Dam are represented in the Gunnison River model. In the model, the Gunnison River below the Aspinall Unit is divided into five sections, known as reaches. The first reach, labeled CrystaltoGunnisonTunnel, extends from Crystal Reservoir to the start of the Black Canyon at the river gage downstream of the Gunnison Tunnel. This reach accounts for releases from Crystal Reservoir and diversions to the Gunnison Tunnel and calculates flows in the Black Canyon. The second reach extends from the start of the Black Canyon down to the river gage in the town of Delta. This reach incorporates tributary flows from the Smith Fork

and the North Fork of the Gunnison River as well as all other measurable tributary flows between Crystal Dam and the river gage in Delta. The third reach extends from Delta to the river gage near the town of Whitewater. This reach incorporates flows from the Uncompahgre River as well as tributary flows from other smaller streams entering the mainstem of the Gunnison River between Delta and Whitewater. The fourth reach extends from the Whitewater gage to the Redlands Diversion Dam. The fifth and final reach extends from the Redlands diversion dam to the river gage below the Redlands Diversion Dam. This reach accounts for diversions from the Gunnison River to the Redlands Canal.

The model separates annual reservoir operations into 3 time periods: January-March, April-July, and August-December. Basic daily input data to the model are: historic Blue Mesa Reservoir inflows, both actual and unregulated; historic side inflows to Morrow Point and Crystal; Gunnison Tunnel diversions; and various downstream gains computed from actual gage data. Other data provided as input to the model include forecasted inflow and tunnel demands for each forecast period.

Reservoir inflow forecast data and forecasted tunnel demands are for the current forecast period and are generally set on the first day of the month and also on the fifteenth if available. Forecast data for the last month of the forecast period must generally be adjusted (sometimes daily) to reflect the improved accuracy which occurs at the end of the forecast period. The model determines remaining forecasted inflow and demand by subtracting the inflows or demands to date from the most recent forecast data available. Remaining minimum canyon demands, which include trout spawning and incubation flows, are computed at various times in the model since these demands are dependent upon flows that occur during the model run.

Based on forecasted inflows, forecasted demands (Gunnison Tunnel and Black Canyon requirements), and storage or release of storage, a volume of water that should be released before the end of the forecast period is determined. This volume is generally referred to as the operation volume. Operation volume is converted to a daily flow rate (cfs) and added to the required downstream releases to compute the desired total release. Actual releases equal this desired release unless policy or physical constraints are triggered. Required downstream releases include tunnel diversion and canyon requirements. Canyon requirements include a minimum flow of 300 cfs and the flow needed to minimize impacts to the spawning and incubation of brown and rainbow trout.

The following is a general description of how the model works:

<u>Weekly Determination</u>

Forecasted inflows, estimated demands and target contents are used to determine preliminary operational releases. On the 1st, 8th, 15th, and 22nd of each month the model makes an estimate of operational volume to release between the current date and the end of forecast period. The operational volume can be defined as the water in excess of estimated demands (filling Blue Mesa Reservoir and identified releases).

The operational release volume is changed to a flow rate based on the remaining days in the forecast period. This operational release rate remains constant until the next estimate is made. The model may modify the operational release under the following circumstances:

- Factors are applied in January, April, October, & November to increase power in January and reduce flows during trout spawn periods.
- Operational releases June 15 to July 31 may be increased at the expense of Blue Mesa Reservoir storage if it is anticipated that higher operation releases will be needed from August through December to reach the December 31 elevation target.
- Operational releases in August through October, which would result in bypass of Crystal Powerplant, are reduced if it is determined this water could be run through the powerplant in November and December.

Daily Determination

Aspinall target release is then set equal to Gunnison Tunnel plus Operational Release plus minimum Black Canyon Flow (300 cfs, or minimum trout target hydrograph) and adjusted if necessary.

Aspinall target release may be modified under the following conditions:

- Bypasses of inflow (Blue Mesa Reservoir is not allowed to store when it is anticipated that storing water would result in less than 750 cfs at the Redlands diversion).
- Release may be increased if current operations anticipate Blue Mesa Reservoir content to exceed 820,000 af within 7 days.
- Release may increase if current rate of fill indicates Blue Mesa Reservoir will reach elevation of 7518 ft or greater within 20 days.
- Release will increase if Blue Mesa Reservoir has encroached on required flood control storage according to Flood Control Diagram. Normal ramping rates may be exceeded in these instances.
- Decrease release based on Gunnison River at Delta flows exceeding 14,000 cfs.
- January through March: Crystal releases are limited to the amount which can be utilized in the powerplant.

Constraints which may be applied to the computed release include ramping rates in the Black Canyon, flood control decisions both at Blue Mesa Reservoir and Delta, and power plant limitations.

At Blue Mesa Reservoir, the daily release is set to be “Canyon Requirement + Gunnison Tunnel Demand - Side Inflow to Crystal and Morrow Point + Crystal Operation Release”. Blue Mesa Reservoir daily release may be reset by other constraints:

1. If the desired Blue Mesa Reservoir release results in Blue Mesa Reservoir exceeding its maximum content, release is increased.
2. Blue Mesa Reservoir release is reduced if flow at Delta exceeded 14,000 cfs on the previous day.
3. Blue Mesa Reservoir release adjusted if ramping rates (either up or down) in the canyon are exceeded.
4. Blue Mesa Reservoir release is increased if the minimum brown or rainbow trout spawning or incubation flow, or the minimum canyon flow of 300 cfs is not met. (Can occur due to tunnel diversion changing.)
5. During Jan-Mar release are limited so that all releases at Crystal go through the powerplant.
6. Blue Mesa Reservoir release will be increased, subject to downstream ramping criteria, if with the current rate of fill, Blue Mesa Reservoir would have less than 2 ft of storage space remaining at the end of 7 days. Release is the minimum of 6,000 cfs or the release which would result in having 2 feet of storage space remaining.
7. If high fall releases are anticipated, June and July flows may be increased. This provides for additional power generation and more stable canyon flows.

In general, Crystal Reservoir release is equal to the Blue Mesa Reservoir release plus side inflows occurring between Blue Mesa and Crystal reservoirs.

Operation of the Aspinall Unit to maximize peak flows at Whitewater also requires forecasting the time of peak runoff for the North Fork of the Gunnison River, in an attempt to allow releases from Crystal Reservoir to match the North Fork's peak. The required timing of the peak release from Crystal Reservoir was adjusted to closely approximate the timing of the North Fork peak occurring during the last two weeks in May, with the assumption that this level of accuracy in predicting the peak could be reproduced in future operations.

Current depletions are already incorporated by using the historical inflow dataset. Reasonably foreseeable depletions have also been included in all model alternatives. These depletion volumes were developed with the help of the State of Colorado and the Colorado River Water Conservation District. Depletions in the model total about 450,000-500,000 acre-feet per year from the Gunnison River at the Whitewater Gage.

The No Action and action alternatives include full Dallas Creek (17,200 af) Project depletions. Historic depletions are depicted in the gage records which the model is based upon. Future depletions are modeled by assuming the applicable projects' full depletion amount is used each year of the 1975-2005 study period and spread over each year of the study period using a monthly variable distribution.

Also included are all depletions that could occur without further federal action (primarily exercise of state water rights not presently being used as identified by the State of Colorado), and all depletions for which favorable biological opinions did not depend on implementing the action. Depletions used for the alternatives appear in Table 1.

Table 1. Estimated depletions consulted on as part of the biological assessment.

Project	Estimated average annual depletion (af)
Aspinall Unit	10,000
Uncompahgre Project	155,000
Dallas Creek Project	17,200
Paonia Project	10,000
Smith Fork Project	6,000
Bostwick Park Project	4,000
Fruitgrowers Project	4,100
State, local, and private water uses	210,000-260,000 (general estimate)
Dolores Project	99,200*
Future Water uses	3,500
Upper Gunnison Subordination	30,800
Total for Gunnison Basin (excludes Redlands)	450,000-500,000

*The Dolores Project consultation addressed a 131,000 af depletion. Updated information indicates actual depletions are approximately 99,200 af.

The model in its present configuration represents the best science available to assess the impacts of implementing operation alternatives on various resources associated with the Gunnison Basin.

Modeling Assumptions

Because of the limitations of the modeling environment, many assumptions were made in the development of the Gunnison River model and the Alternative rulesets. It is recognized that under actual operations, there may be opportunities to match peaks outside of the model parameters. The assumptions that are specific to this model are described below:

1. It is assumed that the timing of the peak flow of the North Fork of the Gunnison River can be predicted accurately five days prior to its occurrence. The peak of the North Fork is known (within the May 15 to May 31 window as stated in the Flow Recommendations) and ramping up at Crystal Reservoir to coincide with this peak occurs five days prior to the peak date. In order to meet the spring peak flow targets while minimizing impacts to other authorized purposes of the Aspinall Unit, it is desired to time spring peak releases from Crystal Reservoir with the spring peak of the North Fork of the Gunnison River. While the date of the North Fork peak is known exactly in the model, releases at Crystal still may not be timed exactly with the peak due to ramping rate constraints that may require a period of greater than five days to reach the needed release at Crystal to meet the spring peak flow target at the Whitewater gage.
2. It is assumed that decisions regarding the operation of the Aspinall Unit to target a spring peak and possibly duration days above a target threshold, will be made as of the release of the May 1 forecast from the CBRFC. While the spring peak target is set by the May 1 forecast, if the forecast were to change significantly at a later time, the duration day targets could be modified for that year.

3. It is assumed that the historic hydrology of the Gunnison River Basin (from 1975 to 2005) will be representative of future hydrology. In reality this could be considered unlikely and possibly misleading if the impacts of global climate change significantly alter the hydrology of the Gunnison Basin. Therefore, the analysis of how well these different operations meet the flow recommendations assumes that historic hydrologic conditions will be repeated in the future. If this assumption is not correct, Flow Recommendations may be more difficult or less difficult to meet.

Variables Inherent in the Operation of Aspinall Unit

A number of variables common to the action alternatives may affect the ability to maintain any prescribed pattern of releases from the Aspinall Unit. They include the following:

Inflow forecasts: Reservoir inflow forecasts are provided bi-weekly from January through the end of the runoff season. However these forecasting techniques may not accurately predict the volume of available spring runoff. Forecasted runoff volumes can change by large amounts with each new forecast leading to wide fluctuations in the anticipated reservoir water availability. Often times operational decisions are made based on a forecasted runoff volume that may change drastically later on in the runoff period. Figure 1 shows the historical inflow forecasts for Blue Mesa Reservoir and how the forecasts change throughout the year as well as the differences from the actual inflow volumes for that runoff year. These forecast volumes are categorized based on the hydrologic categories described in the Flow Recommendations. Regardless of these fluctuations, each alternative would pass inflows required for downstream senior direct flow water rights in accordance with Colorado State water law.

Dry	0 D
Mod Dry	381 MD
Avg Dry	561 AD
Avg Wet	709 AW
Mod Wet	871 MW
Wet	1123 W

Blue Mesa April thru July unregulated inflow (1000 AC-FT)

		(1000 AC-FT)												est		est	Apr-Jul	Gunnison R
YEAR	JAN	FEB	MAR	APR	mid april	MAY	mid may	JUN	mid june	JUL	July 8	mid july	July 22	Actual	Whitewater
1965		1020 MW	970 MW	1100 MW	1100 MW	1100 MW	1100 MW	1100 MW		1060 MW				1095 MW	
1966		470 MD	680 AD	450 MD	385 MD	320 D	350 D	380 D		485 MD				484 MD	
1967		890 MW	860 AW	540 MD	495 MD	450 MD	450 MD	450 MD		460 MD				444 MD	
1968		730 AW	715 AW	560 MD	580 AD	600 AD	645 AD	690 AD		665 AD				637 AD	
1969		860 AW	840 AW	880 MW	808 AW	735 AW	693 AD	650 AD		710 AW				733 AW	
1970		900 MW	870 AW	740 AW	780 AW	820 AW	820 AW	850 AW		955 MW				947 MW	
1971		730 AW	730 AW	550 MD	550 MD	550 MD	535 MD	520 MD		690 AD				690 AD	
1972	830 AW	775 AW	650 AD	570 AD	570 AD	570 AD	535 MD	500 MD		505 MD				484 MD	
1973	910 MW	940 MW	780 AW	780 AW	815 AW	850 AW	815 AW	780 AW		770 AW				779 AW	
1974	700 AD	900 MW	800 AW	700 AD	700 AD	730 AW	665 AD	600 AD		555 MD				552 MD	
1975	750 AW	780 AW	820 AW	980 MW	980 MW	1000 MW	960 MW	920 MW	850 AW	810 AW	830 AW	846 AW	846 AW	850 AW	AW
1976	670 AD	550 MD	640 AD	610 AD	610 AD	580 AD	580 AD	580 AD	580 AD	480 MD	480 MD	478 MD	478 MD	478 MD	MD
1977	470 MD	300 D	250 D	240 D	240 D	240 D	220 D	200 D	200 D	160 D	160 D	166 D	166 D	167 D	D
1978	800 AW	950 MW	835 AW	1000 MW	950 MW	900 MW	900 MW	940 MW	930 MW	830 AW	820 AW	813 AW	813 AW	811 AW	AW
1979	840 AW	1200 W	1100 MW	1150 W	1100 MW	1050 MW	1050 MW	1000 MW	1000 MW	935 MW	930 MW	934 MW	934 MW	934 MW	MW
1980	650 AD	965 MW	900 MW	1050 MW	1050 MW	1100 MW	1100 MW	1050 MW	1050 MW	995 MW	980 MW	959 MW	959 MW	955 MW	MW
1981	550 MD	420 MD	305 D	350 D	335 D	280 D	328 D	375 D	375 D	270 D	270 D	280 D	280 D	231 D	D
1982	810 AW	862 AW	840 AW	870 AW	870 AW	856 AW	856 AW	830 AW	815 AW	735 AW	740 AW	740 AW	740 AW	740 AW	AW
1983	640 AD	580 MD	500 MD	640 AD	665 AD	690 AD	715 AW	740 AW	740 AW	885 MW	890 MW	891 MW	891 MW	892 MW	W
1984	1300 W	1170 W	1100 MW	1130 W	1203 W	1275 W	1313 W	1350 W	1350 W	1435 W	1430 W	1433 W	1433 W	1433 W	W
1985	970 MW	950 MW	855 AW	850 AW	888 MW	925 MW	925 MW	950 MW	950 MW	1065 MW	1060 MW	1043 MW	1043 MW	1041 MW	W
1986	950 MW	810 AW	930 MW	880 MW	940 MW	1000 MW	1000 MW	950 MW	950 MW	1025 MW	1030 MW	1033 MW	1033 MW	1034 MW	MW
1987	765 AW	765 AW	700 AD	675 AD	675 AD	675 AD	675 AD	675 AD	750 AW	810 AW	800 AW	790 AW	790 AW	788 AW	MW
1988	650 AD	700 AD	650 AD	570 AD	545 MD	520 MD	440 MD	380 D	380 D	395 MD	390 MD	391 MD	391 MD	391 MD	MD
1989	670 AD	625 AD	680 AD	590 AD	519 MD	448 MD	448 MD	429 MD	429 MD	440 MD	440 MD	443 MD	443 MD	443 MD	MD
1990	450 MD	500 MD	450 MD	450 MD	433 MD	415 MD	370 D	324 D	330 D	385 MD	380 D	382 MD	382 MD	382 MD	MD
1991	600 AD	525 MD	475 MD	550 MD	575 AD	600 AD	573 AD	545 MD	545 MD	605 AD	600 AD	601 AD	601 AD	600 AD	AD
1992	625 AD	590 AD	540 MD	600 AD	570 AD	540 MD	520 MD	500 MD	500 MD	450 MD	460 MD	464 MD	464 MD	465 MD	AD
1993	605 AD	680 AD	920 MW	950 MW	985 MW	1020 MW	1020 MW	1020 MW	1020 MW	1010 MW	1000 MW	989 MW	989 MW	987 MW	W
1994	580 AD	525 MD	550 MD	510 MD	535 MD	560 MD	560 MD	580 AD	580 AD	530 MD	520 MD	514 MD	514 MD	512 MD	MD
1995	630 AD	650 AD	740 AW	850 AW	850 AW	950 MW	1020 MW	1100 MW	1100 MW	1310 W	1310 W	1300 W	1249 W	1242 W	W
1996	560 MD	860 AW	900 MW	870 AW	870 AW	900 MW	850 AW	820 AW	820 AW	840 AW	840 AW	830 AW	831 AW	830 AW	AD
1997	1050 MW	1100 MW	1050 MW	900 MW	950 MW	1000 MW	1000 MW	1000 MW	1050 MW	1045 MW	1050 MW	1035 MW	1060 MW	1062 MW	MW
1998	660 AD	660 AD	630 AD	600 AD	650 AD	690 AD	600 AD	600 AD	520 MD	550 MD	560 MD	565 AD	564 AD	565 AD	AD
1999	500 MD	595 AD	520 MD	460 MD	460 MD	600 AD	600 AD	540 MD	600 AD	650 AD	660 AD	656 AD	673 AD	676 AD	AD
2000	475 MD	450 MD	550 MD	630 AD	630 AD	550 MD	550 MD	565 AD	565 AD	505 MD	500 MD	505 MD	504 MD	504 MD	MD
2001	630 AD	550 MD	550 MD	550 MD	560 MD	530 MD	530 MD	485 MD	510 MD	495 MD	500 MD	505 MD	504 MD	505 MD	MD
2002	500 MD	445 MD	410 MD	310 D	270 D	205 D	190 D	180 D	175 D	163 D	160 D	158 D	157 D	156 D	D
2003	575 AD	485 MD	520 MD	510 MD	500 MD	485 MD	450 MD	450 MD	450 MD	450 MD	440 MD	420 MD	432 MD	430 MD	MD
2004	680 AD	630 AD	620 AD	460 MD	460 MD	460 MD	425 MD	425 MD	415 MD	415 MD	420 MD	415 MD	421 MD	422 MD	MD
2005	720 AW	825 AW	805 AW	770 AW	770 AW	750 AW	735 AW	670 AD	640 AD	605 AD	600 AD	590 AD	590 AD	588 AD	AW

Figure 1. Historical April-July unregulated inflow forecasts for Blue Mesa Reservoir with hydrologic categories from the Flow Recommendations.

Fluctuations in North Fork of the Gunnison River contributions: Flow contributions from the North Fork of the Gunnison River have a significant effect on the ability of the Action Alternative to meet recommended flow targets. The North Fork, like any unregulated river, experiences a wide range of flows due to snowmelt and rain events. Limited snowpack information in this subbasin along with the relatively short travel times to the confluence with the mainstem Gunnison River, create difficulties in predicting the timing of runoff on the North Fork. Matching Aspinall Unit releases with North Fork flows, given the uncertainties in the timing and magnitude of the peak runoff as well as the other issues listed below, complicate Reclamation's ability to achieve the targeted flows set in the Action Alternative.

Unanticipated precipitation events: Extreme runoff events that occur on any tributaries that enter the Gunnison River downstream from Morrow Point Reservoir can affect Reclamation's ability to achieve the flow targets of the Action Alternative. Longer duration events may cause adjustments in the release from the Aspinall Unit. Also, unanticipated high inflows into the Unit could require additional releases to avoid the occurrence of an uncontrolled spill. Reclamation will continue to closely monitor weather conditions during high flow or high release periods in an attempt to avoid releases that would increase the potential for flooding.

Travel time: An adjustment in water releases from the Aspinall Unit takes two to three days travel time to reach the Whitewater gage near Grand Junction. During this travel

time, changes in tributary flows downstream of the Aspinall Unit can influence the ability to achieve the target flow at the Whitewater gage.

Gage errors: Gage errors are inherent with all measuring equipment, and changing river channel and flow conditions (i.e., sand deposits and erosion) compound gage errors.

Maintenance needs: Dam releases can be interrupted due to a variety of unforeseen events such as mechanical problems, repair of gates, downstream emergencies and other factors. In addition, regularly scheduled maintenance needs and inspections may impact Reclamation's ability to make specific releases.

Safety Concerns*:* The Black Canyon and Gunnison Gorge are home to Colorado's Premiere Gold Medal Brown Rainbow Trout fishery. Many anglers frequent the area at all times of year. In some areas the characteristically narrow and steep canyon walls cause flow changes to result in rapid changes in water elevation. Without advanced warning, wading fishermen can become stranded on an island or the opposite river bank.

Operational Uncertainties

Uncertainties are recognized in both the EIS alternatives for the Aspinall Unit re-operation and in the overall recovery plan for the endangered fish. Responses of the endangered fish to the Flow Recommendations and other recovery elements have been predicted based on scientific studies of the fish and their habitats, but only actual scientific monitoring conducted through the Recovery Program will determine the status and trends of the endangered fish and their habitats following implementation of the Preferred Alternative and other recovery activities. Also, it is uncertain to what extent non-native fish will benefit from the recommended flows and whether these benefits will offset the positive effects of the modified hydrology on endangered fish. The Recovery Program, which includes Federal, State, Tribal, and water development interests, would be responsible for conducting monitoring and research, and for communicating results of this work to stakeholders and the public during Aspinall Unit operation meetings. The Recovery Program can also recommend recovery actions that would address all of the recovery factors related to the endangered fish. These actions may include experimentation to test new hypotheses, modifications to the Preferred Alternative, or control actions directed against non-native fish, if warranted by monitoring and research results. Any adjustments in, or modifications to, the Flow Recommendations must be approved by the Coordination Committee, which is the governing committee of the Recovery Program. Recommendations for dam release modifications can then be considered by Reclamation, the agency ultimately responsible for unit operations. Thrice-yearly Aspinall Unit operation meetings will provide a forum for all interested parties to discuss Aspinall Unit operations and recovery program progress and recommendations. Representatives of the Recovery Program and other scientists will be invited to each meeting to discuss the effects of dam operations and other resource management actions on the endangered fish. Flexibility in dam releases, discussed later in this appendix, will also be discussed at these meetings. Future changes in the Preferred Alternative, dam

operations and other management policies could be implemented long-term after compliance with applicable law.

Hydrologic Modeling Analysis

Introduction

This appendix details the analysis process for determining impacts to hydrology from operation of the No Action Alternative, and the Action Alternatives. The results of this modeling effort are also presented. Understanding the impact of the alternatives on the water resources of the Gunnison River basin requires modeling the complex relationships associated with multiple diversions and tributaries within the basin.

Riverware was selected primarily because of its flexible capability to simulate all key features within the Gunnison River Basin. Riverware has been used in the Gunnison River Basin since about 1998 in assessing the impact of the Black Canyon Water Right in the Gunnison River Basin. This model development has been completed by the U.S. Bureau of Reclamation (Reclamation).

Impact Analysis Results

The water supply impacts of operating the Aspinall Unit to meet the Flow Recommendations are most visible at Blue Mesa Reservoir. Storage contents at Morrow Point and Crystal Reservoirs do not change significantly between the alternatives as water surface elevations remain relatively constant during operation of the Aspinall Unit. Therefore only reservoir content at Blue Mesa was analyzed to determine water supply impacts from operating to meet the Flow Recommendation targets under the various criteria in each alternative.

The annual maximum content at Blue Mesa Reservoir is shown in table 2. Annual maximum content is a good measure of impacts to water supply as it shows how filling Blue Mesa Reservoir can be compromised while trying to meet the Flow Recommendation targets. In almost all instances, the peak on the Gunnison River occurs before the reservoir fills so large releases of water to achieve the peak flow target will be reflected in reduced annual storage at Blue Mesa Reservoir. In the wettest of years, differences in maximum annual content from the No Action Alternative may not be that significant as runoff in the Gunnison Basin may far exceed the capacity of Blue Mesa Reservoir. However, in drier years, even with reduced peak flow targets, there can be substantial decreases in the volume of water stored in the reservoir.

Table 2: Maximum Annual Content at Blue Mesa Reservoir

Blue Mesa Max Annual Content (acre-ft)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	791207	796903	764922	764922	764922
1976	740929	670190	646116	606406	646116
1977	545907	527592	518203	489706	518203
1978	724465	719626	586253	468923	586253
1979	777988	780358	634009	492607	634009
1980	781646	793830	783121	459032	783121
1981	558609	548739	550583	238615	550583
1982	744961	746838	710612	597144	710612
1983	829625	815217	816975	816579	816306
1984	829625	829625	829625	829625	829625
1985	829628	823088	807001	806149	806722
1986	813215	812178	802030	631365	802036
1987	815075	811088	809775	808092	809775
1988	700966	695537	673872	630057	695639
1989	741423	732362	701289	654522	741470
1990	640602	629735	615015	584606	635236
1991	800911	801608	790491	769085	789942
1992	774132	772438	740617	687412	772692
1993	814208	816860	815789	816001	822199
1994	786505	787163	756217	695660	786145
1995	825174	828276	827922	816873	828221
1996	788793	799006	737451	697778	737509
1997	816842	815213	813413	705622	813413
1998	731826	725361	737554	734748	737554
1999	810950	808166	784521	740467	796219
2000	756879	756394	667007	725673	757246
2001	785706	785706	728053	758013	785706
2002	569324	569128	573154	572231	569128
2003	542365	500171	485819	461014	505679
2004	667346	582263	539832	470883	587105
2005	711318	706386	709932	680083	704264
Average	743489	735066	708296	651932	720118

Table 3: End of Month Contents at Blue Mesa Reservoir for No-Action Alternative

	Blue Mesa End of Month Content (ac-ft)											
					No Action							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	514685	519816	509464	409228	396325	650416	791149	739725	662208	614177	611726	587145
1976	586285	582351	583395	575570	661022	739654	683794	651171	604766	573260	574307	578343
1977	582369	585167	582365	546853	503815	471947	414877	361782	331143	314930	326227	333434
1978	340330	342332	353386	314492	374899	672120	713904	652233	598951	571687	580255	580467
1979	534136	448137	366498	331586	443765	711769	769996	714314	648787	605550	595261	581003
1980	583937	499655	449459	400306	480821	741916	759924	691519	646129	622736	608289	580425
1981	570041	570768	553460	523419	508438	549169	530007	490702	475310	460970	468738	484196
1982	487449	474212	492002	453386	489928	711075	736558	734713	724174	700392	649374	579792
1983	561707	545938	538161	507924	591263	827807	814270	800294	743377	681240	643005	582046
1984	490783	401758	330195	252257	681714	827762	812356	814326	772179	753695	682398	581093
1985	499355	444986	459616	524120	760935	820997	807247	752757	719480	696688	655076	579784
1986	509722	498615	445620	444707	540775	799937	806441	779417	749238	716830	672528	580075
1987	549193	534355	547420	595418	784319	813824	778353	727574	665172	615086	606912	580740
1988	580856	571770	582507	582860	622944	700966	639347	593103	568171	552251	568039	578145
1989	584359	581745	589095	633957	697648	733077	659320	616764	556457	536856	543941	550515
1990	555606	557872	557359	521242	541683	638952	602991	570670	546669	560255	579351	579528
1991	577053	579997	589594	615248	713655	799117	782484	731335	681820	628113	618143	579294
1992	574450	571609	573297	589926	696723	774132	739801	701695	651206	606617	598694	580246
1993	584363	576221	501860	439503	640033	813282	806028	760822	707268	658274	619775	580215
1994	566751	555368	549666	550873	697288	785228	712301	664082	631828	617593	604035	579825
1995	574751	581125	546065	482442	512735	819067	802527	804070	766519	716609	663081	580207
1996	556833	515040	443111	430929	621661	781892	762011	704324	657640	646528	628215	580508
1997	485696	399443	361514	400280	607747	815704	811848	796286	760819	723442	661616	580318
1998	563844	549819	537967	526221	601970	715157	716013	683354	632701	610038	606155	579783
1999	584377	583693	578252	559351	678299	803893	809042	803842	769843	710361	650851	580401
2000	556868	537684	512756	531203	702990	747438	681275	639832	606070	571578	581309	580393
2001	578616	583465	581590	584652	742021	784704	730443	708400	642201	598768	595429	580226
2002	578884	578612	580930	570651	541926	502155	438421	369525	334454	326146	333730	335657
2003	336007	336310	340882	327130	437650	540714	501534	455671	441298	418941	428312	433163
2004	436320	436940	465896	497292	604600	664930	618719	567351	528169	516557	526484	531962
2005	540018	514552	507653	479155	546360	702919	680537	654346	607341	592377	586776	580718
Avg	536311	518044	503582	490393	594386	724572	706888	668903	626819	597372	582840	554182
Max	586285	585167	589594	633957	784319	827807	814270	814326	772179	753695	682398	587145
Min	336007	336310	330195	252257	374899	471947	414877	361782	331143	314930	326227	333434

End of month contents at Blue Mesa Reservoir for the No Action Alternative and for Alternatives A, B, C and D are summarized in tables 3 through 7. At the bottom of each table the average end of month content is calculated along with the maximum and minimum end of month contents for the 31 year period of analysis.

Table 4: End of Month Contents at Blue Mesa Reservoir for Alternative A

	Blue Mesa End of Month Content (ac-ft)											
					Alt A							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	498173	487156	479086	425899	438420	680660	796846	745416	666498	617209	613334	587144
1976	585609	582002	580304	572878	576046	670190	631902	600104	566237	546023	558094	563634
1977	567775	569839	565483	528528	485432	445486	379725	323646	291600	274290	285287	290795
1978	296273	294212	304590	286162	360011	666226	709066	648379	595963	555192	554041	554239
1979	517893	432505	350873	339792	446538	714320	772366	715151	649418	605995	595497	581003
1980	583325	498996	449459	439732	510948	763584	771358	690527	643328	611887	602194	580425
1981	569379	559826	542973	513533	498561	537046	515370	475521	460143	445811	453582	468811
1982	477854	469171	490294	462568	487653	713171	738434	736207	725300	701192	649798	579792
1983	561494	545547	537573	507414	586715	815170	813366	800239	743321	681197	642982	582046
1984	490783	401758	330195	252011	672117	829624	810247	812922	772264	753766	682436	581093
1985	499356	444986	459600	532329	749097	815384	806555	748065	715485	693864	653579	579784
1986	509656	498579	445587	466582	556351	804477	804228	777258	747269	715437	671787	580075
1987	549196	534357	547774	595816	781482	810781	774407	724427	662800	613409	606023	580740
1988	578771	570631	580005	581244	616817	695537	635242	582472	560113	546554	562525	573338
1989	581316	580147	589095	634006	687656	724019	650270	606068	548618	529021	536108	542683
1990	546744	546199	545403	509255	529707	627926	594762	553725	530475	544069	567337	574725
1991	574057	578245	589594	615248	720401	799936	783181	731891	682241	628411	618300	579294
1992	572379	562998	564600	583474	692709	772438	738109	700337	650183	605894	598310	580246
1993	579844	573722	499545	486693	711159	816789	804036	758832	705768	657214	619213	580215
1994	567029	555889	550456	551881	698355	785831	712904	664376	632049	617750	604118	579825
1995	574755	581127	546065	508584	549164	819920	789153	800002	762455	713503	662055	580207
1996	557643	515459	443192	465176	666493	796333	772217	712512	663810	650890	630528	580508
1997	485650	399418	361514	399818	591111	814744	811913	796176	760725	723376	661581	580318
1998	563862	549853	538017	526265	592170	708151	709552	678171	628795	607277	604691	579783
1999	584348	582677	578252	559630	610823	789972	803690	801866	768044	709091	650177	580401
2000	557204	538324	513721	532040	703695	746954	680791	637006	603940	570072	580510	580393
2001	578616	583465	581590	584652	742021	784704	730443	708400	642201	598768	595429	580226
2002	578884	578612	580753	570455	541656	492016	416039	346526	311480	303189	310781	311537
2003	308899	305907	309763	295228	395751	497029	431101	366392	352864	330564	339964	343693
2004	345398	343817	373009	404477	511873	581892	542888	479244	440593	429026	438974	444296
2005	452368	459156	469671	451159	537794	697575	675780	650530	604465	590345	585643	580718
Avg	525630	507245	493485	489759	588669	716706	696966	657174	615756	586138	572093	543935
Max	585609	583465	589594	634006	781482	829624	813366	812922	772264	753766	682436	587144
Min	296273	294212	304590	252011	360011	445486	379725	323646	291600	274290	285287	290795

Table 5: End of Month Contents at Blue Mesa Reservoir for Alternative B

	Blue Mesa End of Month Content (ac-ft)											
					Alt B							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	498173	487156	479086	425899	396341	599919	764863	713460	642415	600184	604307	587145
1976	585299	581842	581484	576063	550616	645860	615877	586084	555494	536619	548692	554233
1977	558375	560441	556089	519139	476051	436117	370371	314304	282269	264966	275967	281477
1978	286957	284900	295283	277626	280172	497037	581688	534120	491595	450345	449829	450116
1979	443321	358857	330501	321823	442468	576737	631152	584882	550130	529162	537466	544385
1980	551649	481484	449459	441787	493537	743532	760655	680011	634564	604136	597823	580425
1981	569219	559481	544029	515380	500407	538889	517211	477361	461981	447647	455419	470647
1982	478999	469773	490780	463005	467735	666501	702226	707358	703558	686435	642025	579792
1983	566377	554659	551365	519398	601261	814170	808018	796713	739798	678655	641634	582046
1984	490783	401758	330195	252256	681614	827004	810848	813036	772362	753849	682479	581093
1985	499356	444986	459582	532306	731296	804302	806285	747795	715255	693702	653493	579784
1986	509652	498577	445585	466586	540353	714661	801829	775287	745472	714166	671112	580076
1987	549200	534359	548097	596179	770705	809775	773689	723854	662368	613104	605861	580740
1988	578804	570648	580114	581366	592363	673872	620972	568480	547062	536507	552479	563294
1989	574433	576531	589095	634064	654411	694204	626752	584887	532345	512756	519846	526423
1990	530487	529945	529155	493018	513485	613770	584764	544007	520764	534361	557632	566448
1991	568588	574200	589594	615248	692000	787553	772074	723024	675787	623848	615881	579294
1992	573382	564152	567138	585968	659887	740617	706318	674833	630962	592306	591106	580246
1993	579984	573672	499499	486648	719102	815768	805918	760713	707186	658216	619744	580215
1994	566766	555396	549709	550928	637386	755023	682125	638427	612494	603925	596788	579825
1995	574432	580957	546065	509914	505757	817832	802466	803352	765802	716061	662787	580207
1996	556984	515118	443126	465110	569729	728820	710707	663167	626622	624600	616588	580509
1997	485924	399571	361514	402903	569558	809095	811476	796163	760713	723368	661577	580318
1998	563864	549857	538023	526270	608773	721365	721738	687947	636162	612485	607452	579783
1999	584403	582706	578252	559127	598276	744118	771617	780482	748579	695349	643020	580401
2000	560838	545247	524156	541097	635099	663460	617086	576946	549831	525818	540021	550932
2001	559001	567098	576104	580357	655912	727335	673129	662555	607651	574344	582479	580226
2002	578433	578355	582570	574482	545679	496034	420053	350534	315484	307190	314780	315535
2003	312897	309903	313756	299218	381385	482680	416772	352081	338568	316279	325683	329415
2004	331124	329547	358748	390227	469248	539503	500187	436586	397974	386434	396394	401725
2005	409806	416604	427139	419963	541400	701417	679151	653234	606503	591785	586446	580718
Avg	518629	501219	490816	487850	563936	683451	673162	635861	597992	571245	559897	535080
Max	585299	582706	589594	634064	770705	827004	811476	813036	772362	753849	682479	587145
Min	286957	284900	295283	252256	280172	436117	370371	314304	282269	264966	275967	281477

Table 6: End of Month Contents at Blue Mesa Reservoir for Alternative C

	Blue Mesa End of Month Content (ac-ft)											
					Alt C							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	498173	487156	479086	425899	396341	599919	764863	713460	642415	600184	604307	587145
1976	585299	581842	581484	576063	526619	604494	586858	556960	526935	508072	520151	525697
1977	529844	531915	527573	490641	447581	407683	341982	285955	253954	236674	247685	253203
1978	258690	256642	267043	251922	260767	423287	462661	415900	373482	332305	331826	332138
1979	325369	287668	308928	303759	430537	486839	348973	304036	271498	250704	259092	266072
1980	273571	274602	272228	278558	358195	452871	395464	311699	278136	249486	251310	252150
1981	253540	243641	230247	202772	188200	227138	205963	166542	151521	137420	145304	160611
1982	174213	182756	204040	231953	305312	460731	532528	566154	597144	611206	602138	579792
1983	575217	570457	583116	550787	626131	816579	812008	799932	743015	680963	642858	582046
1984	490783	401758	330195	252034	681521	829159	687815	591598	585344	618246	610590	581094
1985	498954	444775	480926	562644	758030	798847	805790	747301	714835	693404	653335	579784
1986	509645	498573	445581	466595	539990	580674	627972	617265	620722	626160	624590	580076
1987	548120	533792	569913	621502	762405	807983	772650	723025	661744	612662	605627	580740
1988	578736	570613	580109	581423	544162	629154	587768	535512	514118	503577	519557	530377
1989	541521	551745	587658	632765	625402	642997	589275	548230	498881	479308	486406	492990
1990	497059	496524	495747	459632	480132	583445	559364	517332	494110	507720	530997	539817
1991	544832	550070	568471	599978	680915	765364	750686	705947	663016	614820	611094	579294
1992	574628	565200	570928	589992	656736	687168	663074	640567	605138	574050	581427	578580
1993	577637	572439	498386	485536	716604	812946	768978	728689	683051	641154	610698	580215
1994	571224	563764	562403	567133	587247	695151	632589	591972	572748	574496	580520	579825
1995	574361	580920	546065	510227	500445	811717	781489	537623	540576	554857	577549	580207
1996	578453	526737	446663	470446	572780	686633	671865	632077	603192	608036	607806	580509
1997	486139	399695	361514	405069	571691	697000	657949	676677	670522	659624	627781	580318
1998	579487	577071	578173	562277	634707	718324	718933	685697	634467	611286	606817	579783
1999	584390	582700	578252	559245	595117	690159	720809	739649	714352	671228	630238	580402
2000	567286	557528	542669	557163	671118	717084	652542	611614	584477	556313	570509	580393
2001	578616	583465	581590	584652	694948	757013	702779	686341	625577	587016	589197	580226
2002	578555	578424	582245	573558	544757	495112	419132	349615	314566	306272	313863	314618
2003	311980	308987	312840	298303	356553	457880	392007	327349	313863	291592	301004	304743
2004	306458	304888	334103	365605	403987	470552	431323	367801	329260	317766	327748	333095
2005	341191	348008	358579	368970	501996	668891	653897	633060	591300	581037	580452	579781
Avg	480451	468205	463444	464100	536159	628477	603225	558567	528192	509601	508144	494701
Max	585299	583465	587658	632765	762405	829159	812008	799932	743015	693404	653335	587145
Min	174213	182756	204040	202772	188200	227138	205963	166542	151521	137420	145304	160611

Table 7: End of Month Contents at Blue Mesa Reservoir for Alternative D

	Blue Mesa End of Month Content (ac-ft)											
					Alt D							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	498173	487156	479086	425899	396341	599919	764863	713460	642415	600184	604307	587145
1976	585299	581842	581484	576063	550616	645860	615877	586084	555494	536619	548692	554233
1977	558375	560441	556089	519139	476051	436117	370371	314304	282269	264966	275967	281477
1978	286957	284900	295283	277626	280172	497037	581688	534120	491595	450345	449829	450116
1979	443321	358857	330501	321823	442468	576737	631152	584882	550130	529162	537466	544385
1980	551649	481484	449459	441787	493537	743532	760655	680011	634564	604136	597823	580425
1981	569219	559481	544029	515380	500407	538889	517211	477361	461981	447647	455419	470647
1982	478999	469773	490780	463005	467735	666501	702226	707358	703558	686435	642025	579792
1983	566377	554659	551365	519398	574114	816306	812197	799981	743064	681001	642878	582046
1984	490783	401758	330195	252030	681533	826915	809561	812857	772207	753718	682410	581093
1985	499355	444986	459611	532342	730868	804074	806279	747789	715251	693698	653491	579784
1986	509652	498577	445585	466587	540380	714687	801835	775293	745478	714170	671114	580076
1987	549200	534359	548095	596177	770704	809775	773689	723855	662369	613104	605861	580740
1988	578804	570648	580114	581366	616932	695639	635310	582525	560153	546583	562553	573367
1989	581334	580157	589095	634006	697697	733124	659366	614137	554698	535099	542184	548758
1990	552818	552272	551474	515323	535769	633296	598448	557598	534345	547936	571204	576513
1991	575121	578973	589594	615248	692483	786987	771525	722585	675456	623614	615757	579294
1992	573455	564081	567138	585999	694426	772692	738362	700540	650336	606002	598368	580246
1993	579828	573714	499537	486686	718979	817185	807182	761908	708086	658853	620081	580215
1994	566599	555083	549235	550322	696705	784898	711972	663623	631482	617349	603905	579825
1995	574746	581122	546065	508623	504594	817485	801201	803049	765499	715830	662663	580207
1996	557047	515151	443133	465117	569894	728878	710766	663214	626657	624625	616602	580509
1997	485924	399571	361514	402899	569551	809087	811475	796162	760713	723368	661577	580318
1998	563864	549857	538023	526270	608773	721365	721738	687947	636162	612485	607452	579783
1999	584403	582706	578252	559127	598276	759061	785270	791129	758271	702192	646647	580401
2000	559027	541798	518958	536586	707486	747805	681642	637689	604455	570436	580703	580393
2001	578616	583465	581590	584652	742021	784704	730443	708400	642201	598768	595429	580226
2002	578884	578612	580753	570455	541656	492016	416039	346526	311480	303189	310781	311537
2003	308899	305907	309763	295228	401265	502536	436601	371884	358351	336047	345445	349172
2004	350877	349294	378483	409946	517336	586787	548545	484895	446239	434670	444616	449937
2005	458008	464794	475307	455313	537414	695275	673837	648971	603290	589514	585179	580718
Avg	522439	504693	493535	490014	576006	695006	683462	645166	606073	578121	565756	539464
Max	585299	583465	589594	634006	770704	826915	812197	812857	772207	753718	682410	587145
Min	286957	284900	295283	252030	280172	436117	370371	314304	282269	264966	275967	281477

Another measure of the impact of meeting the Flow Recommendations on the water supply of the Aspinall Unit is to determine the amount of storage used from Blue Mesa Reservoir. Storage usage at Blue Mesa Reservoir is divided into three time periods: January through March, April to the date the reservoir fills (or reaches its maximum content for that year) and from the date of fill through the end of December. This division coincides with operational divisions within the Gunnison River model. Additionally, water demands for spring peaks and duration flows usually occur within the April to max fill date time period while baseflow demands usually occur within the max

Table 8: Blue Mesa Reservoir Storage Usage from Jan 1 to Mar 31 for Alternatives A, B, C, D as compared to the No Action Alternative.

Blue Mesa Storage Usage (acre-ft) Difference from No Action (Jan 1 - Mar 31)				
	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0
1976	-3091	-1911	-1911	-1911
1977	-2173	-2166	-2146	-2166
1978	-6157	-6146	-6112	-6146
1979	0	0	0	0
1980	0	0	0	0
1981	-10487	-9431	0	-9431
1982	0	0	0	0
1983	0	0	0	0
1984	0	0	0	0
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	-2502	-2393	-2398	-2393
1989	0	0	0	0
1990	-4124	-4112	-4087	-4128
1991	0	0	0	0
1992	-8698	-6159	-2369	-6159
1993	0	0	0	0
1994	0	0	0	-431
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	0
2001	0	0	0	0
2002	-177	0	0	-177
2003	-6999	-7004	-7003	-6999
2004	-3416	-3401	-3373	-3422
2005	0	0	0	0
Average	-1543	-1378	-948	-1399

fill date to end of December period or the January through March period. Table 7 shows the annual volume of storage lost from Blue Mesa Reservoir from January through March for each action alternative as compared to the No Action Alternative. Storage usage during this three month time period occurs during efforts to achieve baseflow targets in the Gunnison River as measured at the Whitewater gage. Storage usage mainly occurs during drier years or years that follow a significant dry period.

Table 9 shows the annual volume of storage lost from Blue Mesa Reservoir from April to the time of maximum reservoir content. Again all storage usage volumes are relative to the No Action Alternative. This time period coincides with the months where spring peak

Table 9: Blue Mesa Reservoir Storage Usage from Apr 1 to the date of fill for Alternatives A, B, C, and D as compared to the No Action Alternative.

Blue Mesa Storage Usage (acre-ft) Difference from No Action Apr 1 - Max Fill Date)				
	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0
1976	-67649	-92902	-132613	-92902
1977	-1434	-1428	-1410	-1428
1978	0	-80109	-169199	-80109
1979	0	-45821	-187224	-45821
1980	0	0	-145383	0
1981	0	0	0	0
1982	0	-33127	0	-33127
1983	0	0	0	0
1984	0	0	0	0
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	-2927	-24701	-68511	-2933
1989	-9061	-40134	-85465	0
1990	0	0	0	0
1991	0	0	0	0
1992	0	-27357	-84352	0
1993	0	0	0	0
1994	0	-30288	-90846	0
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	0
1998	-6465	0	0	0
1999	-1705	-25349	-69403	-13651
2000	-485	-89872	-31206	0
2001	0	-52168	-27693	0
2002	-19	0	0	-19
2003	-11075	-29420	-53310	-5567
2004	0	-20366	-64670	0
2005	0	0	0	0
Average	-3252	-19130	-39074	-8889

targets as well as half bankfull and bankfull targets are trying to be met. Consequently in some years large volumes of storage are used when attempting to meet the Flow Recommendation targets. Years with the biggest impacts appear to be moderately dry years with spring peak targets and more average years with duration targets.

Table 10: Blue Mesa Reservoir Storage Usage from the date of fill to Dec 31 for Alternatives A, B, C, D as compared to the No Action Alternative.

Blue Mesa Storage Usage (acre-ft) Difference from No Action (Max Fill Date - Dec 31)				
	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0
1976	0	0	0	0
1977	-24324	-24253	-24030	-24253
1978	-21390	0	0	0
1979	0	0	-29550	0
1980	0	0	-5662	0
1981	-5514	-5523	-3591	-5523
1982	0	0	0	0
1983	0	0	0	0
1984	0	0	0	0
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	0	0	0	-1757
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	0	0
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	0
2001	0	0	0	0
2002	-23924	-20122	-21039	-23924
2003	-47276	-47202	-47069	-47304
2004	-2583	-2722	-2404	-1784
2005	0	0	0	0
Average	-4033	-3220	-4301	-3372

Table 10 shows the annual volume of storage lost from Blue Mesa Reservoir from the date of fill through the end of December. Storage usage during these months is primarily for meeting baseflow targets in the Gunnison River. Impacts to storage from baseflow

releases during this time are the most significant in the driest of years and sometimes carry over from very dry years into the next year.

Impacts to flatwater recreation on Blue Mesa Reservoir may be measured by changes in reservoir surface area. Tables 11 through 13 show Blue Mesa Reservoir surface area, measured in acres, at three different times during the year. The end of April is an approximation of the start of the recreation season at Blue Mesa Reservoir. The date of

Table 11: Blue Mesa Reservoir surface area at the end of April.

Blue Mesa End of April Surface Area (acres)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	6514	6663	6663	6663	6663
1976	7744	7726	7747	7747	7747
1977	7560	7440	7378	7175	7378
1978	5600	5304	5211	4923	5211
1979	5775	5856	5676	5490	5676
1980	6432	6781	6798	5221	6798
1981	7406	7340	7353	4333	7353
1982	6889	6961	6964	4691	6964
1983	7303	7300	7380	7585	7380
1984	4927	4924	4927	4925	4925
1985	7411	7465	7465	7661	7465
1986	6821	6992	6992	6992	6992
1987	7859	7861	7863	8004	7863
1988	7789	7779	7780	7780	7780
1989	8072	8072	8073	8066	8072
1990	7392	7312	7193	6938	7352
1991	7969	7969	7969	7885	7969
1992	7828	7792	7806	7829	7806
1993	6780	7146	7145	7137	7146
1994	7586	7592	7586	7690	7582
1995	7113	7307	7316	7318	7308
1996	6707	6981	6981	7022	6981
1997	6432	6428	6456	6476	6456
1998	7425	7425	7425	7659	7425
1999	7640	7642	7639	7640	7639
2000	7458	7463	7522	7626	7493
2001	7799	7799	7774	7799	7799
2002	7712	7711	7737	7731	7711
2003	5730	5400	5442	5433	5400
2004	7225	6470	6339	6107	6520
2005	7088	6872	6610	6139	6904
Average	7096	7090	7071	6828	7089

maximum content could be considered to approximate the peak of the recreation season. The end of August is a close approximation to the end of the recreation season which probably tapers off significantly after Labor Day weekend.

Table 12: Blue Mesa Reservoir surface area as of the date of fill.

Blue Mesa Max Annual Surface Area (acres)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	8954	8987	8796	8796	8796
1976	8654	8269	8138	7920	8138
1977	7554	7434	7372	7168	7372
1978	8566	8540	7808	7010	7808
1979	8875	8889	8072	7190	8072
1980	8897	8969	8905	6933	8905
1981	7635	7572	7584	4770	7584
1982	8675	8686	8491	7869	8491
1983	9179	9095	9105	9103	9102
1984	9179	9179	9179	9179	9179
1985	9179	9141	9047	9042	9045
1986	9083	9077	9018	8058	9018
1987	9094	9071	9063	9053	9063
1988	8439	8409	8290	8051	8410
1989	8657	8608	8441	8183	8657
1990	8108	8049	7968	7798	8079
1991	9011	9015	8949	8821	8946
1992	8852	8841	8652	8365	8843
1993	9089	9105	9099	9100	9136
1994	8926	8930	8743	8410	8924
1995	9153	9171	9169	9105	9171
1996	8939	9000	8635	8421	8636
1997	9105	9095	9085	8464	9085
1998	8605	8571	8636	8621	8636
1999	9070	9054	8914	8651	8983
2000	8747	8744	8252	8572	8750
2001	8921	8921	8585	8754	8921
2002	7704	7703	7728	7722	7703
2003	7530	7247	7139	6949	7288
2004	8254	7785	7514	7025	7812
2005	8495	8468	8488	8324	8457
Average	8682	8633	8480	8111	8549

Table 13: Blue Mesa Reservoir surface area at the end of August.

Blue Mesa End of August Surface Area (acres)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	8647	8678	8507	8507	8507
1976	8165	7885	7807	7625	7807
1977	6070	5694	5598	5301	5598
1978	8171	8150	7477	6574	7477
1979	8511	8516	7800	5492	7800
1980	8387	8382	8324	5571	8324
1981	7176	7061	7075	3861	7075
1982	8621	8629	8474	7684	8474
1983	9007	9007	8986	9005	9006
1984	9090	9082	9082	7838	9081
1985	8722	8694	8692	8689	8692
1986	8883	8870	8859	7981	8859
1987	8583	8566	8563	8558	8563
1988	7846	7786	7699	7486	7787
1989	7978	7919	7800	7569	7963
1990	7712	7604	7541	7366	7629
1991	8603	8606	8558	8466	8556
1992	8443	8435	8295	8108	8436
1993	8771	8759	8771	8589	8778
1994	8235	8237	8096	7840	8233
1995	9030	9006	9026	7500	9024
1996	8457	8502	8230	8062	8230
1997	8984	8983	8983	8305	8983
1998	8342	8314	8368	8355	8368
1999	9028	9017	8890	8647	8953
2000	8104	8089	7752	7949	8092
2001	8479	8479	8227	8359	8479
2002	6144	5923	5962	5953	5923
2003	6907	6114	5977	5732	6166
2004	7691	7089	6756	6127	7132
2005	8182	8162	8176	8067	8153
Average	8225	8137	8011	7457	8069

Reoperation of the Aspinall Unit for Flow Recommendation purposes will create differences in the historic release pattern of water from the Aspinall Unit reservoirs. Higher releases during May for spring peaks and higher flows of extended duration will result in lower releases during months of traditionally high power demand. During dry periods extended releases for baseflows may result in minimum releases from the Aspinall Unit during months when releases were higher historically.

Table 14: Monthly water volumes through the Blue Mesa Powerplant for the No Action Alternative

	Blue Mesa Monthly Power Volume (Acre-Ft)												
	No Action												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	14467	14201	35022	152813	184381	57572	94752	125352	113815	83954	43264	52259	971852
1976	26835	26510	27771	75275	52341	81864	125224	86855	82909	60021	21713	13333	680651
1977	10746	14342	23955	72787	78716	78375	80694	76992	52193	37345	13120	16057	555321
1978	17673	13957	22049	118088	111339	51707	96812	105233	78872	51549	16908	21561	705748
1979	70061	106581	117154	127291	139638	70966	119320	119649	105091	75965	40637	43339	1135692
1980	25285	109763	81704	146582	186777	131020	121122	121209	93672	64020	43279	56376	1180808
1981	33088	20565	42311	62874	65022	59946	74834	78351	50703	44063	17046	10103	558906
1982	21949	34053	17179	106331	141966	60090	111703	99106	93763	87149	87264	98275	958830
1983	46858	41304	49652	85447	75828	104529	184652	131889	113295	108133	71667	97995	1111248
1984	121349	114712	104990	158818	90469	184400	190621	126921	117226	94315	114051	138059	1555930
1985	109942	77147	36578	80094	92625	183304	155199	121030	101537	82434	83983	105393	1229267
1986	99533	40709	115653	125996	146670	111264	187342	118989	102842	94750	93164	122627	1359540
1987	59033	43054	41456	76165	77558	177383	124978	109253	105856	84371	37988	50560	987657
1988	24128	30982	20478	53280	57802	64068	119040	88122	57458	45303	10527	13124	584313
1989	20378	26053	36821	48747	56140	83591	125867	93001	86934	50571	15467	13291	656861
1990	15176	15564	27690	70201	59292	55214	100209	74249	56009	25589	18002	25347	542542
1991	25701	18953	25391	44304	88213	114431	110323	103505	82457	77043	41467	61565	793354
1992	27157	25562	28877	47772	31290	64346	113938	94716	90936	79085	36071	42066	681817
1993	22936	34317	109895	137438	131251	165380	150632	118792	105153	95554	68957	64974	1205280
1994	39017	34339	43175	64650	28793	89703	121208	83993	68142	57179	42663	49217	722079
1995	28240	18927	83445	123467	174237	174450	197633	132229	112428	103473	91803	112840	1353173
1996	53060	74824	112274	121666	138187	94383	113958	105176	87781	60082	57064	82902	1101358
1997	124351	110452	82330	64023	109629	152151	144952	113500	111237	108121	101546	111197	1333488
1998	45816	40858	55168	70352	102326	63293	115243	98368	89788	67101	40428	52089	840830
1999	22201	25431	50136	67551	43020	130353	133067	115198	105638	103859	88765	97533	982751
2000	52031	46626	64614	71851	28610	79907	123782	81360	70528	62902	17682	25426	725318
2001	23610	16605	37337	52095	42907	103995	123398	89096	99968	71611	30170	38200	728991
2002	23017	17760	27062	56919	73640	76881	81086	80715	49999	32299	14830	15838	550048
2003	17628	15984	21800	49662	39275	43039	80910	80229	58258	46768	12534	16117	482205
2004	16729	17757	14422	30095	28602	62931	110986	86125	70290	41205	14340	14498	507979
2005	13018	44321	33389	86913	112962	54078	119655	84090	80259	55937	31960	31045	747628
Average	40355	41039	51283	85469	89984	97568	124295	101397	86937	69411	45754	54620	888112

Changes in hydropower production can be revealed by analyzing the volume of water that runs through the power plant. Tables 14 through 18 show the monthly volumes of water released through the power plant at Blue Mesa Reservoir for the No Action Alternative and Alternatives A, B, C and D. Annual totals are given in the far right column and monthly average volumes over the 31 year study period are shown in the bottom row. Below the tables for the action alternatives, a comparison with the No Action Alternative is provided. Monthly volume differences in acre-feet and a percentage difference are shown for quick comparison to the No Action Alternative.

Table 15: Monthly water volumes through the Blue Mesa Powerplant for Alternative A

Blue Mesa Monthly Power Volume (Acre-Ft) Alt A	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	30980	30354	32754	105876	144580	69379	118373	125352	115214	85210	44688	53867	956626
1976	27511	26183	30513	74878	119854	66421	107708	86067	70399	48743	10694	11831	680801
1977	10633	15079	25514	74241	78792	86477	89431	80025	53644	38471	13434	17767	583508
1978	19102	18033	22753	97661	98347	42722	95761	104253	78008	65059	26633	21580	689912
1979	60078	105973	117154	103469	133583	71103	119499	121181	105297	76149	40847	43575	1097909
1980	25898	109810	81044	107145	161514	139630	131342	133630	95481	72071	38526	50282	1146375
1981	33750	30846	41860	62278	65022	62204	77364	78909	50703	44063	17046	10336	574381
1982	16162	29500	13849	95441	138181	55716	111921	99486	94130	87476	87640	98699	928199
1983	47070	41483	49850	85369	79866	107951	178194	131040	113295	108120	71647	97972	1111856
1984	121349	114712	104990	159072	99839	183894	183704	126216	115738	94328	114084	138097	1556022
1985	109942	77148	36595	71868	103120	185471	150402	125031	100842	81265	82657	103896	1228236
1986	99599	40678	115651	104083	139016	116957	188201	118937	102653	94175	92511	121887	1334348
1987	59030	43055	41104	76122	80794	176076	125884	108457	105083	83677	37200	49671	986153
1988	26213	30035	21843	52395	62317	63375	117720	94654	54892	42945	10346	12417	589151
1989	18614	24609	35223	48698	66184	82665	125867	94654	84082	50571	15467	13291	659926
1990	16208	18376	27978	70239	59292	54275	97421	82975	55269	25589	13833	18138	539592
1991	23894	17710	23640	44304	81184	118967	110445	103645	82593	77166	41606	61722	786876
1992	29228	32103	28967	45531	28855	62029	113938	94383	90602	78786	35732	41683	681836
1993	27456	32297	109713	87921	106755	180880	152883	118792	104663	95115	68459	64412	1149348
1994	38739	34096	42906	64431	28734	90167	121208	84301	68214	57244	42736	49300	722075
1995	28236	18929	83447	97321	151965	184126	198099	125949	112428	102516	89724	111814	1304553
1996	52251	75215	112612	87487	120652	121897	118182	107187	89794	61888	59113	85214	1091493
1997	124396	110432	82304	64485	114333	144071	144082	113675	111221	108093	101515	111162	1329769
1998	45798	40843	55151	70359	104913	60505	114704	97095	88513	65957	39131	50625	833595
1999	22230	26417	49121	67271	100960	88503	124895	111824	105462	103330	88170	96858	985043
2000	51694	46322	64289	71978	28741	81098	123782	83703	69833	62278	16975	24628	725322
2001	23610	16605	37337	52095	42907	103995	123398	89096	99968	71611	30170	38200	728991
2002	23017	17760	27239	56938	73715	86754	93352	81362	49999	32299	14830	17015	574280
2003	20622	19288	22534	50474	49321	44873	107731	99169	57501	46768	12534	17259	548074
2004	18200	19985	14233	30095	28602	53324	103855	98474	69828	41205	14340	14669	506812
2005	13018	12082	15995	76950	93553	50863	119072	83152	79321	55095	31061	29911	660072
Average	40791	41160	50586	76015	89855	97947	125433	103312	86280	69589	45269	54122	880359
Difference from No Action													
percent	1.08%	0.29%	-1.36%	-11.06%	-0.14%	0.39%	0.92%	1.89%	-0.76%	0.26%	-1.06%	-0.91%	-0.87%
acre-feet	436	121	-697	-9454	-130	379	1138	1916	-657	178	-484	-498	-7753

Table 16: Monthly water volumes through the Powerplant for Alternative B

Blue Mesa Monthly Power Volume (Acre-Ft) Alt B	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	30980	30354	32754	105876	164909	102524	70576	125352	107358	78160	36692	44840	930376
1976	27821	26033	29173	72871	143720	65344	99423	84073	67130	47409	10694	11831	685522
1977	10633	15079	25514	74241	78792	86477	89431	80025	53644	38471	13434	17767	583508
1978	19102	18033	22753	96898	142426	128769	54092	91229	68193	65589	26022	21509	754615
1979	30542	105068	63902	101083	126860	157187	116909	110340	74388	53732	22059	22169	984240
1980	20961	95651	63536	105089	162309	134463	122006	133451	93736	71061	35147	45911	1083321
1981	33910	31032	40459	61486	65022	62204	77364	78909	50703	44063	17046	10336	572533
1982	16852	30043	13963	95489	141347	77833	101494	92152	87038	80498	80658	90927	908294
1983	42187	37252	45166	87169	77298	112663	176483	129221	113295	107140	70453	96624	1094951
1984	121349	114712	104990	158855	90524	184500	187257	126703	115754	94343	114123	138141	1551250
1985	109941	77148	36613	71872	103699	193007	139954	125031	100802	81197	82580	103810	1225656
1986	99603	40677	115651	104076	138871	157768	139635	118510	102481	93649	91916	121212	1324048
1987	59027	43057	40783	76082	91884	171265	125597	108313	104942	83550	37057	49510	991066
1988	26180	30051	21751	52382	86329	60606	110342	94386	53960	39947	10346	12417	598698
1989	15454	21343	31608	48640	97960	79262	119596	92335	79187	50571	15467	13291	664713
1990	16208	18376	27978	70239	59292	52223	93275	82705	55269	25589	13833	16711	531696
1991	21087	16287	19595	44304	106465	105851	109180	101414	80183	75277	39463	59303	778411
1992	28225	31952	27582	45575	64173	61059	113938	88117	84332	73160	29350	34479	681941
1993	27316	32488	109708	87921	99259	182215	150382	118792	105126	95530	68930	64943	1142609
1994	39002	34325	43160	64638	87033	60041	121208	79493	61835	51519	36243	41971	720469
1995	28559	18775	83277	95990	154067	170539	197462	131952	112428	103304	91549	112546	1300449
1996	52910	74896	112337	87487	145143	82974	112241	95064	77663	51003	46766	71276	1009761
1997	124123	110553	82457	61399	115142	152057	143509	113251	111219	108090	101511	111158	1334469
1998	45795	40841	55149	70360	95096	63881	115721	99497	90917	68114	41577	53386	840334
1999	22176	26443	49150	67775	102521	106528	111149	101157	103557	97614	81587	89702	959358
2000	48060	43032	60772	73350	89722	96071	104062	80105	63917	52445	13220	13605	738364
2001	13767	13361	26459	50907	108896	75312	123398	77667	88698	61497	18699	25250	683910
2002	23469	17566	25164	54727	73715	86754	93352	81362	49999	32299	14830	17015	570252
2003	20622	19288	22534	50474	67549	44873	107731	99169	57501	46768	12534	17259	566302
2004	18200	19985	14233	30095	57005	53132	104215	98474	69828	41205	14340	14669	535383
2005	13018	12082	15995	65642	58771	50623	119540	83817	79986	55692	31698	30715	617577
Average	38938	40187	47231	75258	103090	103807	117759	100712	82744	66725	42575	50783	869809
Difference from No Action													
percent	-3.51%	-2.08%	-7.90%	-11.95%	14.56%	6.39%	-5.26%	-0.68%	-4.82%	-3.87%	-6.95%	-7.02%	-2.06%
acre-feet	-1417	-853	-4052	-10211	13106	6239	-6536	-685	-4193	-2686	-3179	-3836	-18303

Table 17: Monthly water volumes through the Blue Mesa Powerplant for Alternative C

	Blue Mesa Monthly Power Volume (Acre-Ft) Alt C												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	30980	30354	32754	105876	164909	102524	70576	125352	107358	78160	36692	44840	930376
1976	27821	26033	29173	72871	150173	81605	87110	84201	66585	47409	10694	11831	695505
1977	10633	15079	25514	74241	78792	86477	89431	80025	53644	38471	13434	17767	583508
1978	19102	18033	22753	94389	136368	162946	95612	90539	68193	65589	26022	21509	821055
1979	30542	58332	14311	97592	122524	194571	194550	109311	72438	53732	22059	22169	992132
1980	20783	24521	33988	91239	144248	191994	151447	136922	82159	69485	27109	27743	1001638
1981	21380	31276	38559	60584	65022	62204	77364	78909	50703	44063	17046	10336	557446
1982	11678	12364	13849	40034	86983	108483	65608	63782	52324	49348	45327	51043	600822
1983	33346	30293	29203	87511	83793	126750	178470	129989	113295	108048	71537	97848	1090083
1984	121349	114712	104990	159052	90449	185029	200955	143806	81458	42992	50429	66256	1361476
1985	110344	76957	15054	62860	104159	193015	134996	125031	100729	81074	82441	103652	1190310
1986	99610	40673	115650	104065	138867	200421	135995	102804	69297	56946	50445	74693	1189465
1987	60106	42545	18395	72560	114703	174710	124845	108103	104738	83367	36850	49275	990198
1988	26248	30018	21721	52321	128944	57168	98863	94178	53960	39947	10346	12417	626130
1989	15454	13222	8263	48503	118152	99212	105907	91544	76020	50571	15467	13291	655607
1990	16208	18376	27978	70239	59292	49226	88377	84003	55269	25589	13833	16711	525100
1991	18216	16664	16597	38461	101551	107657	108401	97118	75887	71539	35223	54517	741830
1992	26979	32150	24839	45337	70050	104668	103777	79169	75908	65600	20776	26466	675720
1993	27997	31374	109589	87921	100646	182922	154766	113905	97253	88466	60917	55898	1111653
1994	34544	30414	38830	61118	130229	69829	110924	76448	55152	41217	23086	25704	697496
1995	28630	18742	83240	95677	154052	166881	198474	201643	72082	39360	15608	27313	1101702
1996	31440	84743	120417	85684	145239	104177	108933	87339	70020	44144	38986	62494	983616
1997	123908	110644	82582	59231	114914	203409	143700	79317	81991	81672	71573	77364	1230302
1998	30172	29246	42200	74480	104779	92857	115487	98944	90364	67618	41014	52751	839911
1999	22188	26437	49143	67657	102517	126412	108046	91220	96975	87519	70252	76920	925287
2000	41612	37198	54535	75786	84355	78417	122189	80866	63917	56581	13220	14627	723304
2001	23610	16605	37337	52095	86826	84642	123398	83511	94545	66744	24650	31969	725931
2002	23346	17619	25559	55326	73715	86754	93352	81362	49999	32299	14830	17015	571176
2003	20622	19288	22534	50474	91413	44873	107731	99169	57501	46768	12534	17259	590166
2004	18200	19985	14233	30095	97635	56904	104215	98474	69828	41205	14340	14669	579785
2005	13018	12082	15995	48126	47230	43778	112294	78754	75026	51241	26947	25658	550149
Average	36776	35032	41606	71658	106211	117113	119864	99863	75310	58605	32700	39420	834157
Difference from No Action													
percent	-8.87%	-14.64%	-18.87%	-16.16%	18.03%	20.03%	-3.56%	-1.51%	-13.37%	-15.57%	-28.53%	-27.83%	-6.08%
acre-feet	-3579	-6008	-9677	-13811	16226	19545	-4431	-1534	-11626	-10806	-13054	-15200	-53954

Table 18: Monthly water volumes through the Blue Mesa Powerplant for Alternative D

	Blue Mesa Monthly Power Volume (Acre-Ft) Alt D												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	30980	30354	32754	105876	164909	102524	70576	125352	107358	78160	36692	44840	930376
1976	27821	26033	29173	72871	143720	65344	99423	84073	67130	47409	10694	11831	685522
1977	10633	15079	25514	74241	78792	86477	89431	80025	53644	38471	13434	17767	583508
1978	19102	18033	22753	96898	142426	128769	54092	91229	68193	65589	26022	21509	754615
1979	30542	105068	63902	101083	126860	157187	116909	110340	74388	53732	22059	22169	984240
1980	20961	95651	63536	105089	162309	134463	122006	133451	93736	71061	35147	45911	1083321
1981	33910	31032	40459	61486	65022	62204	77364	78909	50703	44063	17046	10336	572533
1982	16852	30043	13963	95489	141347	77833	101494	92152	87038	80498	80658	90927	908294
1983	42187	37252	45166	87169	97549	98157	179272	130130	113295	108059	71555	97868	1107658
1984	121349	114712	104990	159055	90435	184484	185034	125596	115729	94319	114062	138072	1547837
1985	109942	77147	36584	71866	103716	193048	139732	125031	100801	81196	82579	103808	1225450
1986	99603	40677	115651	104076	138872	157770	139654	118510	102481	93651	91918	121214	1324075
1987	59027	43057	40784	76082	91884	171264	125597	108313	104942	83550	37057	49510	991066
1988	26180	30051	21751	52382	62323	63388	117755	94668	54905	42956	10346	12417	589122
1989	18624	24618	35233	48698	56140	83593	125867	95676	86066	50571	15467	13291	653844
1990	16208	18376	27978	70239	59292	54961	99101	82786	55269	25589	13833	20217	543848
1991	24618	18045	24368	44304	106298	106901	109163	101304	80076	75180	39354	59179	788790
1992	28152	32096	27510	45543	29662	63491	113938	94433	90652	78831	35782	41740	681831
1993	27471	32290	109712	87921	99420	182156	158133	118860	105420	95794	69229	65281	1151687
1994	39169	34471	43322	64769	28826	89451	121208	84123	68029	57078	42548	49087	722081
1995	28245	18924	83442	97282	153990	170196	197592	131916	112428	103233	91442	112422	1301112
1996	52847	74927	112363	87487	145169	83032	112241	95076	77675	51013	46777	71289	1009896
1997	124123	110553	82457	61402	115142	152060	143503	113251	111218	108090	101511	111157	1334468
1998	45795	40841	55149	70360	95096	63881	115721	99497	90917	68114	41577	53386	840334
1999	22176	26443	49150	67775	102521	101101	112424	104152	104505	100460	84801	93329	968837
2000	49872	44670	62523	72666	29494	84035	123782	83870	70001	62429	17146	24820	725310
2001	23610	16605	37337	52095	42907	103995	123398	89096	99968	71611	30170	38200	728991
2002	23017	17760	27239	56938	73715	86754	93352	81362	49999	32299	14830	17015	574280
2003	20622	19288	22534	50474	43804	44873	107731	99169	57501	46768	12534	17259	542557
2004	18200	19985	14233	30095	28602	53887	103088	98474	69828	41205	14340	14669	506607
2005	13018	12082	15995	78428	98022	52783	118718	82769	78938	54751	30694	29448	665645
Average	39512	40521	47985	75811	94137	105163	119268	101729	83962	67927	43590	52257	871862
Difference from No Action													
percent	-2.09%	-1.26%	-6.43%	-11.30%	4.62%	7.78%	-4.04%	0.33%	-3.42%	-2.14%	-4.73%	-4.33%	-1.83%
acre-feet	-844	-518	-3299	-9658	4153	7595	-5027	332	-2974	-1485	-2163	-2362	-16249

Another way of evaluating the impacts to hydropower production at the Aspinall Unit is to count the number of days that the powerplants were bypassed. Bypass flows occur when releases from the dams exceed the capacity of the powerplants. At Blue Mesa Reservoir, water is bypassed around the powerplant when releases must exceed 3400 cfs. Historic operations of the Aspinall Unit generally focused on releasing as much water as possible through the powerplants in order to maximize hydropower production. Redistributing the timing of releases from the Aspinall Unit dams for spring peaks and extended high flow durations will increase the number of days that the powerplants must be bypassed.

Table 19: Number of days per year that water bypasses the powerplant at Blue Mesa Reservoir

Blue Mesa Bypasses Number of Days/Year					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	5	8	20	20	20
1976	0	7	12	17	12
1977	0	0	0	0	0
1978	1	1	15	25	15
1979	0	7	24	57	24
1980	1	12	16	50	16
1981	0	0	0	0	0
1982	1	8	16	20	16
1983	24	24	27	23	27
1984	61	55	59	85	59
1985	24	33	34	35	34
1986	20	32	21	48	21
1987	19	19	18	24	18
1988	0	0	1	7	0
1989	0	0	1	12	0
1990	0	0	0	0	0
1991	2	4	4	9	4
1992	0	0	0	7	0
1993	16	27	28	31	27
1994	0	0	2	13	0
1995	46	53	60	85	59
1996	0	9	20	25	20
1997	22	28	26	48	26
1998	0	5	1	2	1
1999	11	5	14	20	11
2000	0	0	6	2	0
2001	0	0	7	3	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0

Table 19 shows the number of days per year that water was released through the bypass tubes at Blue Mesa Reservoir for the No Action Alternative and Alternatives A, B, C and D. This water bypasses the powerplant and is unavailable for hydropower production.

During very heavy snowpack years, it may be necessary to employ the spillways at the Aspinall Unit reservoirs to pass the large volume of spring runoff water. Generally when a large volume of spring runoff is forecast, Blue Mesa Reservoir is drawn down in advance of the runoff season with the strategy of capturing and storing as much of the spring runoff volume as possible. Operations of the Aspinall Unit that reduce this level of drawdown may increase the chance that the reservoir will spill later on in these wet years. When releases from Blue Mesa Reservoir must exceed 6100 cfs the spillway gates are opened.

Table 20: Number of days per year that water is spilled from Blue Mesa Reservoir

Blue Mesa Spills Number of Days/Year					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	0	0	0	0	0
1980	0	0	0	0	0
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	5	5	6	10	4
1984	17	18	19	42	19
1985	7	6	5	9	5
1986	0	0	0	3	0
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	0	1	1	2	1
1994	0	0	0	0	0
1995	23	26	23	46	23
1996	0	0	7	8	6
1997	2	1	5	13	5
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	1	0	0
2001	0	0	1	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0

Table 20 shows the number of days per year that water is spilled from Blue Mesa Reservoir for the No Action Alternative and for Alternatives A, B, C and D.

Morrow Point Reservoir is much smaller in storage capacity than Blue Mesa Reservoir but the generating capacity of the powerplant is twice that of the powerplant at Blue Mesa. Changes in hydropower production at Morrow Point affect the power producing capability of the Aspinall Unit more than changes at Blue Mesa or Crystal Reservoirs.

Table 21: Monthly water volumes through the Morrow Point powerplant for the No Action Alternative

Morrow Point Monthly Power Volume (Acre-Ft) No Action	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	18241	17756	38768	160692	211894	82071	109112	127332	115532	86583	44936	55261	1068178
1976	31568	31738	32333	81963	64693	90245	127618	88779	84020	61956	24026	16197	735137
1977	13521	16014	24896	75690	82165	80223	82393	78729	53040	39148	15344	18128	579291
1978	19554	16889	26091	129617	133389	85048	106192	107569	80530	53007	19467	22821	800173
1979	70789	111246	123125	138663	168267	98923	124975	121237	105892	76729	42147	44359	1226352
1980	27345	111954	83214	155601	208524	152578	125243	122466	94994	66648	43902	57480	1249949
1981	34276	22962	45529	70706	71168	64728	77774	80774	53065	46576	19585	12793	599936
1982	24330	36726	21193	115780	162506	81445	117877	102308	97781	92065	89365	100640	1042016
1983	48997	43856	53767	93830	111445	170282	234275	141150	116760	110765	74849	101212	1301188
1984	124696	118272	112589	178508	186670	281135	256462	135007	120925	98672	116101	140684	1869721
1985	115977	84017	46158	105283	141033	270326	163670	124765	105057	85830	86982	108333	1437431
1986	102323	44647	121430	136998	170599	136802	229749	123420	107890	100251	96738	126823	1497670
1987	62751	47602	47426	94317	110309	232597	129361	112727	108365	86632	41017	53060	1126165
1988	26543	34262	24908	65415	69959	75968	122910	92144	60162	49506	12992	15566	650334
1989	21471	27585	40849	60972	67812	89959	127793	95477	89221	54066	17187	14871	707262
1990	16597	17603	30208	75911	67757	66428	103749	77096	58942	28844	19284	26984	589403
1991	27656	21201	28759	51211	120880	143962	117566	109395	88417	80913	44163	63941	898065
1992	29096	27809	32135	58787	56592	80403	119498	99016	93626	80808	39016	43880	760663
1993	25163	35867	117634	156574	182309	220299	171015	122654	109373	99256	71451	67083	1378677
1994	40474	36487	46342	72103	49345	104352	124433	87239	70672	58449	44482	51183	785561
1995	30109	20953	86701	136438	208154	246182	306453	143444	116487	107333	95814	115512	1613582
1996	54852	76220	116020	141012	176136	116398	119996	107923	89686	63190	58929	84112	1204474
1997	126514	113476	90029	79277	146186	229572	160257	117085	113256	108621	103714	113617	1501602
1998	48282	43362	59521	79735	131413	78646	120178	100694	91598	69069	42481	53827	918806
1999	23813	27028	53117	73752	59186	158795	140023	121385	110033	107917	90317	99304	1064670
2000	53725	49256	66069	82946	51335	88845	126192	83916	72321	64528	19174	27019	785327
2001	25213	18595	39304	59967	63136	112263	125930	92001	101590	73162	31767	40128	783056
2002	24944	20454	29245	65717	78628	79425	83246	81912	51842	33565	15961	16882	581821
2003	19009	18025	24642	56449	53484	52716	83418	82648	60192	48443	14240	17760	531026
2004	18505	19978	19292	39553	46243	71010	111771	86676	71116	42420	15567	15827	557958
2005	14797	46390	35848	92779	128964	66381	122229	85987	81966	57891	33301	32636	799172
Average	42617	43814	55392	96331	115490	126065	137786	104934	89495	72027	47881	56707	988538

Tables 21 through 25 show the monthly volumes of water released through the power plant at Morrow Point Reservoir for the No Action Alternative and Alternatives A, B, C and D. As with the tables showing Blue Mesa power volumes, annual totals are given in the far right column and monthly average volumes over the 31 year study period are shown in the bottom row. Again, below the tables for the action alternatives, a comparison with the No Action Alternative is provided.

Table 22: Monthly water volumes through the Morrow Point powerplant Alternative A

Morrow Point Monthly Power Volume (Acre-Ft)													
					Alt A								
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	34754	33909	36500	113654	181336	93878	133645	127332	116931	87838	46360	56868	1063007
1976	32245	31411	35076	81566	144973	74802	110102	87991	71510	50678	13008	14695	748056
1977	13408	16752	26455	77144	82240	88325	91131	81761	54490	40275	15658	19838	607478
1978	20983	20965	26795	109190	119977	76064	105141	106589	79665	66517	29192	22840	783916
1979	60807	110639	123125	114841	173675	99142	125154	122768	106098	76913	42356	44595	1200115
1980	27957	112001	82554	116164	206539	161009	135464	134888	96803	74698	39150	51386	1238612
1981	34939	33243	45079	70110	71168	66985	80303	81332	53065	46576	19585	13026	615411
1982	18543	32172	17863	104889	173956	77071	118095	102688	98148	92391	89740	101064	1026621
1983	49209	44034	53965	93752	115482	176967	224574	140302	116760	110752	74829	101190	1301816
1984	124696	118272	112589	178754	196023	278843	241388	134302	119437	98685	116134	140722	1859846
1985	115976	84017	46174	97057	161071	269921	158752	128767	104362	84661	85656	106836	1443250
1986	102389	44616	121428	115084	176869	147826	234252	123368	107701	99675	96086	126083	1495377
1987	62748	47604	47074	94273	113544	229341	130267	111931	107591	85938	40230	52171	1122713
1988	28628	33315	26273	64530	74474	75274	121590	98676	57596	47147	12811	14859	655172
1989	19707	26141	39251	60923	77856	89033	127793	97130	86369	54066	17187	14871	710328
1990	17629	20415	30496	75948	67757	65489	100961	85823	58203	28844	15114	19775	586453
1991	25849	19958	27007	51211	114134	149887	117688	109535	88553	81036	44302	64099	893259
1992	31166	34349	32225	56545	54157	78085	119498	98682	93292	80509	38676	43496	760682
1993	29682	33847	117452	107057	158308	258761	174249	122654	108884	98817	70953	66521	1347185
1994	40195	36244	46073	71884	49286	104816	124433	87547	70745	58513	44555	51266	785558
1995	30105	20954	86703	110292	192953	263073	298854	134143	116487	106376	93735	114486	1568162
1996	54043	76611	116357	106834	165517	146756	124220	109934	91699	64996	60978	86425	1204369
1997	126559	113456	90004	79739	162358	218373	159254	117260	113239	108594	103683	113582	1506100
1998	48264	43347	59504	79742	141259	75859	119639	99420	90324	67925	41184	52363	918830
1999	23842	28015	52101	73473	125380	105286	131462	118011	109857	107389	89722	98630	1063167
2000	53389	48952	65744	83073	51466	90036	126192	86259	71626	63904	18467	26221	785330
2001	25213	18595	39304	59967	63136	112263	125930	92001	101590	73162	31767	40128	783056
2002	24944	20454	29422	65736	78702	89298	95511	82559	51842	33565	15961	18058	606053
2003	22003	21330	25375	57261	63530	54549	110240	101588	59434	48443	14240	18902	596894
2004	19976	22206	19103	39553	46243	61403	104641	99026	70654	42420	15567	15999	556790
2005	14797	14151	18454	82816	109555	63165	121646	85049	81028	57049	32403	31503	711616
Average	43053	43935	54694	86873	119772	127148	138454	106752	88838	72205	47396	56210	985330

Difference from No Action													
percent	1.02%	0.28%	-1.26%	-9.82%	3.71%	0.86%	0.48%	1.73%	-0.73%	0.25%	-1.01%	-0.88%	-0.32%
acre-feet	436	121	-697	-9458	4282	1083	668	1818	-657	178	-484	-498	-3208

Table 23: Monthly water volumes through the Morrow Point powerplant Alternative B

Morrow Point Monthly Power Volume (Acre-Ft)													
					Alt B								
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	34754	33909	36500	113654	213042	132622	84936	127332	109075	80789	38364	47842	1052820
1976	32555	31261	33735	79559	175429	73724	101817	85997	68241	49344	13008	14695	759366
1977	13408	16752	26455	77144	82240	88325	91131	81761	54490	40275	15658	19838	607478
1978	20983	20965	26795	108427	183329	165583	63472	93564	69850	67047	28581	22769	871366
1979	31271	109734	69874	112456	159795	222022	128573	111928	75189	54496	23569	23189	1122095
1980	23020	97842	65046	114108	213460	162713	126128	134708	95057	73689	35771	47015	1188557
1981	35099	33428	43677	69318	71168	66985	80303	81332	53065	46576	19585	13026	613563
1982	19233	32716	17977	104937	182366	103878	107668	95354	91056	85413	82759	93292	1016649
1983	44326	39804	49281	95553	112914	183465	228444	138482	116760	109773	73635	99842	1292276
1984	124696	118272	112589	178509	186769	282004	253881	134789	119453	98701	116173	140766	1866602
1985	115976	84017	46193	97062	162392	276493	147945	128767	104322	84593	85580	106750	1440089
1986	102393	44614	121428	115078	178264	203312	150603	122941	107528	99150	95490	125407	1466208
1987	62744	47605	46753	94233	124686	220907	129980	111787	107451	85812	40086	52009	1124053
1988	28595	33331	26180	64517	99058	72506	114212	98408	56664	44150	12811	14859	665291
1989	16548	22875	35636	60865	111165	85630	121522	94811	81474	54066	17187	14871	716648
1990	17629	20415	30496	75948	67757	63436	96815	85552	58203	28844	15114	18348	578557
1991	23041	18535	22963	51212	142537	133895	116423	107304	86143	79147	42159	61680	885039
1992	30164	34198	30839	56589	89475	77116	119498	92417	87022	74883	32294	36292	760787
1993	29542	34037	117447	107057	150316	263226	171727	122654	109346	99232	71423	67052	1343061
1994	40459	36474	46327	72091	109320	74690	124433	82739	64365	52789	38063	43937	785686
1995	30429	20801	86534	108961	214563	242856	307375	144103	116487	107164	95560	115218	1590051
1996	54702	76292	116082	106834	214305	113879	118278	97811	79568	54110	48631	72486	1152980
1997	126285	113576	90157	76653	166842	215999	154225	116836	113237	108590	103679	113578	1499658
1998	48262	43345	59502	79743	124658	79235	120655	101822	92727	70082	43630	55124	918785
1999	23787	28040	52130	73977	136256	135757	117716	107344	107952	101672	83138	91474	1059243
2000	49755	45662	62227	84446	123105	105010	106472	82662	65711	54071	14712	15198	809030
2001	15371	15351	28426	58779	141275	83581	125930	80571	90320	63048	20296	27179	750125
2002	25395	20261	27347	63525	78702	89298	95511	82559	51842	33565	15961	18058	602025
2003	22003	21330	25375	57261	81891	54549	110240	101588	59434	48443	14240	18902	615256
2004	19976	22206	19103	39553	74646	61211	105000	99026	70654	42420	15567	15999	585361
2005	14797	14151	18454	71508	74773	62926	122114	85714	81693	57646	33039	32306	669121
Average	41200	42961	51340	86115	136984	135382	130420	104279	85303	69341	44702	52871	980898

Difference from No Action													
percent	-3.33%	-1.95%	-7.32%	-10.61%	18.61%	7.39%	-5.35%	-0.62%	-4.68%	-3.73%	-6.64%	-6.76%	-0.77%
acre-feet	-1417	-853	-4052	-10216	21494	9317	-7366	-655	-4193	-2686	-3179	-3836	-7640

Table 24: Monthly water volumes through the Morrow Point powerplant Alternative C

Morrow Point Monthly Power Volume (Acre-Ft) Alt C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	34754	33909	36500	113654	213042	132622	84936	127332	109075	80789	38364	47842	1052820
1976	32555	31261	33735	79559	195752	91133	89504	86125	67696	49344	13008	14695	784368
1977	13408	16752	26455	77144	82240	88325	91131	81761	54490	40275	15658	19838	607478
1978	20983	20965	26795	105918	177672	217427	108888	92874	69850	67047	28581	22769	959768
1979	31271	62998	20282	108964	153683	282556	280492	110899	73238	54496	23569	23189	1225638
1980	22843	26713	35498	100258	191653	279704	185858	138180	83480	72113	27732	28846	1192878
1981	22569	33672	41778	68416	71168	66985	80303	81332	53065	46576	19585	13026	598475
1982	14059	15036	17863	49483	122209	147465	71782	66985	56342	54263	47428	53407	716321
1983	35485	32844	33318	95894	119410	197605	223462	139251	116760	110680	74719	101065	1280493
1984	124696	118272	112589	178732	186639	283713	307395	188055	85157	47349	52478	68881	1753956
1985	116378	83826	24633	88049	164254	276341	142987	128767	104249	84470	85440	106592	1405986
1986	102400	44611	121428	115066	178211	296469	173261	107236	74344	62446	54019	78888	1408380
1987	63824	47093	24365	90712	158296	219404	129228	111577	107247	85629	39879	51775	1129029
1988	28663	33298	26150	64456	147323	69067	102733	98200	56664	44150	12811	14859	698373
1989	16548	14754	12291	60728	138878	107874	107833	94020	78307	54066	17187	14871	717357
1990	17629	20415	30496	75948	67757	60440	91917	86850	58203	28844	15114	18348	571961
1991	20171	18912	19964	45369	138360	144613	115644	103008	81847	75409	37919	56893	858108
1992	28917	34396	28097	56352	96648	127457	109337	83468	78598	67323	23721	28279	762593
1993	30223	32924	117328	107057	151703	262960	194003	117767	101473	92167	63411	58007	1329023
1994	36000	32563	41997	68571	173255	84478	114148	79694	57683	42486	24906	27670	783452
1995	30499	20768	86497	108648	214924	242144	307086	283567	76141	43220	19619	29985	1463098
1996	33232	86139	124162	105031	214284	146682	114970	90085	71925	47252	40852	63705	1138318
1997	126070	113667	90281	74485	166460	285151	174534	82902	84009	82172	73741	79784	1433257
1998	32638	31749	46554	83863	134707	108210	120421	101269	92174	69586	43067	54489	918727
1999	23800	28035	52124	73858	136251	173150	114613	97407	101370	91578	71803	78692	1042680
2000	43307	39827	55990	86882	109157	87355	124599	83423	65711	58207	14712	16220	785390
2001	25213	18595	39304	59967	110222	92910	125930	86415	96167	68296	26247	33897	783164
2002	25273	20313	27742	64124	78702	89298	95511	82559	51842	33565	15961	18058	602948
2003	22003	21330	25375	57261	105816	54549	110240	101588	59434	48443	14240	18902	639181
2004	19976	22206	19103	39553	115322	64983	105000	99026	70654	42420	15567	15999	629808
2005	14797	14151	18454	53992	63232	56081	114868	80651	76734	53195	28288	27249	601693
Average	39038	37806	45714	82516	141201	156037	139117	106847	77869	61221	34827	41507	963701
Difference from No Action													
percent	-8.40%	-13.71%	-17.47%	-14.34%	22.26%	23.78%	0.97%	1.82%	-12.99%	-15.00%	-27.26%	-26.80%	-2.51%
acre-feet	-3579	-6008	-9677	-13815	25711	29972	1331	1913	-11626	-10806	-13054	-15200	-24837

Table 25: Monthly water volumes through the Morrow Point powerplant Alternative D

Morrow Point Monthly Power Volume (Acre-Ft) Alt D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	34754	33909	36500	113654	213042	132622	84936	127332	109075	80789	38364	47842	1052820
1976	32555	31261	33735	79559	175429	73724	101817	85997	68241	49344	13008	14695	759366
1977	13408	16752	26455	77144	82240	88325	91131	81761	54490	40275	15658	19838	607478
1978	20983	20965	26795	108427	183329	165583	63472	93564	69850	67047	28581	22769	871366
1979	31271	109734	69874	112456	159795	222022	128573	111928	75189	54496	23569	23189	1122095
1980	23020	97842	65046	114108	213460	162713	126128	134708	95057	73689	35771	47015	1188557
1981	35099	33428	43677	69318	71168	66985	80303	81332	53065	46576	19585	13026	613563
1982	19233	32716	17977	104937	182366	103878	107668	95354	91056	85413	82759	93292	1016649
1983	44326	39804	49281	95553	139722	167169	225776	139391	116760	110692	74737	101085	1304294
1984	124696	118272	112589	178735	186624	281978	254316	133682	119428	98677	116112	140696	1865805
1985	115977	84017	46163	97055	162487	276127	147723	128767	104321	84592	85578	106748	1439554
1986	102393	44614	121428	115078	178268	203313	150623	122941	107529	99152	95492	125409	1466240
1987	62744	47605	46754	94234	124685	220906	129980	111787	107451	85812	40086	52009	1124053
1988	28595	33331	26180	64517	74480	75287	121625	98690	57609	47159	12811	14859	655143
1989	19718	26150	39261	60924	67812	89961	127793	98152	88353	54066	17187	14871	704245
1990	17629	20415	30496	75948	67757	66175	102641	85633	58203	28844	15114	21854	590709
1991	26572	20293	27735	51211	142053	134944	116407	107194	86036	79050	42049	61556	895102
1992	30091	34342	30768	56557	54964	79548	119498	98732	93342	80554	38727	43554	760677
1993	29698	33839	117451	107057	150477	263067	174318	122722	109640	99495	71722	67390	1346878
1994	40626	36620	46489	72222	49378	104100	124433	87369	70560	58347	44367	51054	785564
1995	30115	20950	86698	110253	214479	242456	306742	143141	116487	107093	95453	115094	1588961
1996	54639	76323	116109	106834	214193	113956	118278	97823	79579	54121	48643	72500	1152996
1997	126286	113576	90157	76656	166844	216001	154218	116836	113237	108590	103679	113578	1499658
1998	48262	43345	59502	79743	124658	79234	120655	101822	92727	70082	43630	55124	918785
1999	23787	28040	52130	73977	136256	123102	118991	110339	108900	104519	86352	95101	1061494
2000	51567	47300	63978	83762	52219	92973	126192	86427	71794	64055	18638	26414	785319
2001	25213	18595	39304	59967	63136	112263	125930	92001	101590	73162	31767	40128	783056
2002	24944	20454	29422	65736	78702	89298	95511	82559	51842	33565	15961	18058	606053
2003	22003	21330	25375	57261	58013	54549	110240	101588	59434	48443	14240	18902	591377
2004	19976	22206	19103	39553	46243	61966	103873	99026	70654	42420	15567	15999	556586
2005	14797	14151	18454	84294	114087	65086	121292	84666	80645	56705	32035	31039	717252
Average	41773	43296	52093	86669	127367	136429	131648	105267	86521	70543	45718	54345	981668
Difference from No Action													
percent	-1.98%	-1.18%	-5.95%	-10.03%	10.28%	8.22%	-4.45%	0.32%	-3.32%	-2.06%	-4.52%	-4.17%	-0.69%
acre-feet	-844	-518	-3299	-9662	11877	10365	-6138	333	-2974	-1485	-2163	-2362	-6870

As with Blue Mesa Reservoir, impacts to hydropower production can be evaluated by counting the number of days that the powerplant at Morrow Point Dam was bypassed. Bypass of the powerplant at Morrow Point occurs when releases from the dam must exceed 5000 cfs.

Table 26: Number of days per year that water bypasses the powerplant at Morrow Point Reservoir

Morrow Point Bypasses Number of Days/Year					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	3	6	6	6
1976	0	1	0	4	0
1977	0	0	0	0	0
1978	0	0	4	7	4
1979	0	0	9	36	9
1980	0	7	12	34	12
1981	0	0	0	0	0
1982	0	0	5	3	5
1983	12	14	16	14	16
1984	31	27	31	62	32
1985	17	16	19	24	19
1986	2	4	12	40	12
1987	6	5	5	4	5
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	3	15	16	24	14
1994	0	0	0	4	0
1995	35	39	48	76	47
1996	0	0	17	22	17
1997	12	8	11	35	11
1998	0	0	0	0	0
1999	0	1	8	16	6
2000	0	0	3	0	0
2001	0	0	3	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0

Table 26 shows the number of days per year that water was released through the bypass tubes at Morrow Point Reservoir for the No Action Alternative and Alternatives A, B, C and D. This water bypasses the powerplant and is unavailable for hydropower production.

Spillway usage at Morrow Point Reservoir is rare, primarily because almost all of the inflow to the reservoir is controlled by releases at Blue Mesa Reservoir. The maximum release capacity of the powerplant and bypass tubes at Morrow Point is 6500 cfs which exceeds the same combined capacity at Blue Mesa Reservoir. However, when Blue Mesa Reservoir is forced to release water through the spillway gates, the probability becomes high that the spillways at Morrow Point dam will have to be used. When releases from Morrow Point Reservoir must exceed 6500 cfs the spillway gates are opened.

Table 27: Number of days per year that water is spilled from Morrow Point Reservoir

Morrow Point Spills Number of Days/Year					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	1	1	1
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	0	0	0	0	0
1980	0	0	0	0	0
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	5	6	7	9	6
1984	19	21	20	40	19
1985	8	6	9	16	9
1986	0	0	0	0	0
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	0	3	4	4	4
1994	0	0	0	0	0
1995	25	28	25	44	26
1996	0	0	5	6	5
1997	2	1	5	15	5
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	1	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0

Crystal Reservoir is the smallest of the Aspinall Unit reservoirs in terms of storage capacity and powerplant capacity. The reservoir is primarily used to re-regulate or stabilize the fluctuating releases from Morrow Point Reservoir before this water reaches the Black Canyon of the Gunnison River. Changes in hydropower production at Crystal Reservoir have the least impact on the power producing capability of the Aspinall Unit.

Table 28: Monthly water volumes through the Crystal powerplant for the No Action Alternative

	Crystal Monthly Power Volume (Acre-Ft)												
	No Action												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	26314	23059	44512	125525	135546	108448	122585	131477	119443	92053	49089	61911	1039962
1976	42146	39618	39061	89352	80662	103878	131480	93053	86574	66382	29499	22457	824162
1977	20136	19128	26844	78915	86691	83440	86483	82834	55136	43297	20352	22783	626042
1978	23787	21320	32214	124835	127960	128221	125711	113001	84427	56371	25215	25674	888735
1979	72463	117707	131485	126952	135736	128120	131947	125015	107882	78558	45570	46678	1248112
1980	31980	115278	85556	128166	135587	131428	131696	125505	98140	72612	45360	59983	1161291
1981	36956	26584	50421	79270	79118	72741	84622	86427	58514	52294	25299	18810	671057
1982	29670	40764	27280	115982	133794	109979	129276	109697	106913	103042	94110	105938	1106444
1983	53813	47712	60003	102990	132080	127650	130063	127215	120642	115797	81978	108418	1208359
1984	125344	117257	121888	125618	130486	122103	129414	126615	121483	108113	115127	126639	1470088
1985	125561	94364	60582	121168	130043	123637	130636	127283	111706	93510	93722	114934	1327146
1986	108573	50589	125536	124565	132057	126021	131901	129145	119172	112237	104749	129370	1393917
1987	71064	54453	56443	114005	122119	126196	126173	120608	114155	91785	47822	58679	1103502
1988	31964	39221	31628	78647	85557	95588	125688	101347	66370	58995	18530	21050	754584
1989	23959	29909	46960	74297	82795	100553	125722	101241	94517	61968	21085	18427	781433
1990	19813	20689	34050	82182	78658	84930	111925	83679	65674	36214	22188	30673	670676
1991	32047	24607	33880	58776	121476	125395	128795	122343	101885	89651	50214	69259	958328
1992	33461	31220	37081	70795	88930	106191	128649	108832	99810	84762	45630	47954	883316
1993	30143	38221	126021	128325	135870	128329	127829	125479	117495	105163	77068	71826	1211768
1994	43776	39748	51158	80255	75634	117889	125505	94709	76510	61418	48588	55596	870786
1995	34298	24017	91648	121565	132227	124224	125625	127402	120818	115180	104785	121487	1243277
1996	58877	78348	120331	124058	132076	123482	126117	114280	94129	70245	63142	86837	1191922
1997	125809	113741	101650	95888	129945	125098	129275	121338	116738	109863	108600	119054	1396998
1998	53818	47146	66116	89980	124665	101739	127294	106123	95821	73565	47124	57738	991129
1999	27443	29464	57645	80548	79896	117935	126750	125326	118313	116066	93819	103275	1076478
2000	57546	53235	68308	95046	80393	103642	125295	89839	76500	68276	22566	30609	871255
2001	28833	21612	42326	68573	85795	118669	125296	98719	105385	76738	35391	44466	851803
2002	29276	24532	32593	75323	85104	83777	88357	84824	56150	36514	18556	19260	634266
2003	22135	21120	28966	63881	71700	68715	89315	88287	64698	52285	18088	21465	610654
2004	22494	23351	26665	49878	68825	84399	113836	88144	73151	45244	18358	18830	633175
2005	18790	49532	39603	99087	121702	86666	122758	90460	85963	62365	36334	36222	849483
Average	47171	47663	61240	96595	107843	109325	121484	108718	94649	77760	52515	60526	985489

Tables 28 through 32 show the monthly volumes of water released through the power plant at Crystal Reservoir for the No Action Alternative and Alternatives A, B, C and D. The format of these tables is identical to the tables provided for Blue Mesa and Morrow Point Reservoirs.

Table 29: Monthly water volumes through the Crystal powerplant for Alternative A

	Crystal Monthly Power Volume (Acre-Ft) Alt A												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	42827	39213	42245	121806	131099	119696	123750	125378	118420	93309	50513	63519	1071773
1976	42823	39291	41804	88954	108323	88666	114571	92265	74065	55103	18480	20955	785300
1977	20023	19866	28403	80369	86766	91542	95221	85867	56587	44424	20666	24494	654228
1978	25216	25396	32918	117392	118816	121684	120852	112021	83563	69881	34940	25692	888371
1979	62481	112148	125582	121160	128116	122585	126131	124279	108087	78742	45780	46914	1202005
1980	32593	114641	84897	121262	128733	129259	129199	128646	99948	80201	40608	53889	1143875
1981	37619	36865	49970	78674	79118	74998	87152	86985	58514	52294	25299	19043	686532
1982	23882	36211	23950	113265	130122	109725	126430	110077	107280	102766	94485	106362	1084555
1983	54025	47890	60201	102912	129267	125135	129611	127204	120674	115805	81958	108396	1203076
1984	125382	117292	121905	125678	130222	122340	128495	126338	121123	108025	114941	126250	1467991
1985	125170	94365	60598	120363	127761	123812	130917	128046	111156	92341	92396	113437	1320360
1986	108639	50559	125999	123535	130158	124348	130297	126207	118157	110891	104097	126333	1379220
1987	71060	54455	56091	113145	121672	126255	126708	119909	113381	91091	47035	57790	1098592
1988	34049	38274	32993	77762	89355	94894	126069	107879	63804	56636	18349	20343	760407
1989	22195	28466	45362	74248	90040	99627	126185	102894	91665	61968	21085	18427	782161
1990	20844	23502	34338	82220	78658	83991	109137	92406	64934	36214	18018	23464	667726
1991	30240	23363	32128	58776	120815	126001	128438	122466	102020	89774	50354	69417	953793
1992	35532	37761	37172	68553	86495	104362	128286	108499	99476	84462	45291	47570	883460
1993	34662	36201	125520	124144	130942	124865	127959	125479	117295	104938	76570	71264	1199840
1994	43498	39505	50889	80036	75574	118175	125506	95017	76582	61483	48661	55679	870606
1995	34294	24019	91650	119968	128718	123428	125546	126456	120261	114385	102706	120470	1231902
1996	58067	78739	120386	121308	127845	124062	126375	116291	96142	72051	65191	89150	1195607
1997	125861	113721	101625	96351	128162	124944	129533	121520	116803	109835	108572	119019	1395946
1998	53800	47131	66099	89987	123401	100042	126875	104849	94547	72422	45827	56274	981255
1999	27472	30450	56630	80268	97701	106579	126237	125139	118147	115811	93224	102600	1080258
2000	57209	52931	67983	95173	80524	104792	125335	92182	75806	67653	21859	29811	871257
2001	28833	21612	42326	68573	85800	118688	125336	98719	105385	76738	35391	44466	851867
2002	29276	24532	32770	75342	85178	93650	100623	85470	56150	36514	18556	20436	658498
2003	25129	24424	29699	64693	79651	70548	114578	107227	63941	52285	18088	22607	672869
2004	23965	25580	26476	49878	68825	74792	106705	100493	72689	45244	18358	19002	632007
2005	18790	17293	22208	89248	112514	83450	122367	89522	85025	61524	35435	35089	772466
Average	47595	47603	60349	95001	107754	108288	121627	110185	93923	77897	52024	59941	982187

Difference from No Action													
percent	0.90%	-0.13%	-1.46%	-1.65%	-0.08%	-0.95%	0.12%	1.35%	-0.77%	0.18%	-0.94%	-0.97%	-0.34%
acre-feet	425	-60	-892	-1594	-89	-1037	142	1467	-725	137	-491	-585	-3301

Table 30: Monthly water volumes through the Crystal powerplant for Alternative B

	Crystal Monthly Power Volume (Acre-Ft) Alt B												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	42827	39213	42245	121806	130832	108287	109193	125240	112986	86259	42517	54492	1015897
1976	43133	39141	40463	86948	114394	87419	106286	90271	70796	53769	18480	20955	772055
1977	20023	19866	28403	80369	86766	91542	95221	85867	56587	44424	20666	24494	654228
1978	25216	25396	32918	117124	126275	123958	84663	98997	73748	70411	34329	25622	838656
1979	32945	111216	78903	119838	128280	124909	111890	112921	77178	56325	26992	25508	1006907
1980	27656	101166	67388	120341	129064	124878	125728	125869	98203	79212	37229	49518	1086252
1981	37779	37050	48569	77883	79118	74998	87152	86985	58514	52294	25299	19043	684684
1982	24573	36754	24065	111914	127496	92118	117466	102743	100188	96483	87503	98590	1019892
1983	49142	43659	55517	104712	127438	124040	129265	127147	120722	115294	80764	107048	1184748
1984	125439	117346	121931	125728	130482	122085	129071	126886	121475	108173	115223	126767	1470607
1985	125683	94365	60617	120747	127860	123657	128898	126956	110787	92273	92320	113351	1317513
1986	108642	50557	124989	122491	128810	118086	128200	125543	117728	110340	103502	125653	1364541
1987	71057	54456	55770	112926	120641	125093	126034	119737	113240	90965	46892	57628	1094438
1988	34016	38290	32900	77749	99174	92126	123112	107611	62872	53638	18349	20343	760182
1989	19035	25199	41747	74190	101326	96224	125038	100575	86770	61968	21085	18427	771582
1990	20844	23502	34338	82220	78658	81938	104991	92135	64934	36214	18018	22037	659830
1991	27433	21940	28084	58776	121358	126119	127459	120260	99611	87885	48211	66998	934133
1992	34529	37610	35786	68597	100180	100951	128014	102233	93207	78836	38909	40366	859219
1993	34522	36392	125262	123881	132381	124652	127762	125462	117474	105143	77041	71795	1201766
1994	43761	39735	51143	80243	100724	98796	125624	90209	70203	55758	42168	48350	846713
1995	34618	23866	91480	119198	127516	124357	125579	126943	120468	114972	104531	121188	1234715
1996	58727	78421	120287	121546	126977	111147	125332	104168	84011	61166	52844	75212	1119837
1997	124786	113134	101778	93264	127100	125300	127734	120786	116268	109832	108509	119015	1387506
1998	53797	47129	66097	89987	122624	102300	125699	107251	96950	74579	48274	59036	993723
1999	27417	30476	56658	80772	97058	111735	125493	121365	116271	110830	86641	95445	1060160
2000	53575	49641	64466	96545	100414	103764	112147	88584	69890	57820	18104	18788	833739
2001	18990	18368	31449	67385	106004	96992	125329	87289	94114	66625	23920	31516	767981
2002	29727	24339	30695	73131	85178	93650	100623	85470	56150	36514	18556	20436	654469
2003	25129	24424	29699	64693	88475	70548	114576	107227	63941	52285	18088	22607	681691
2004	23965	25580	26476	49878	86128	74600	107065	100493	72689	45244	18358	19002	649478
2005	18790	17293	22208	77940	93892	83103	122668	90186	85690	62120	36072	35892	745856
Average	45735	46630	57172	94285	111375	105141	117849	107529	90441	75085	49335	56617	957194

Difference from No Action													
percent	-3.04%	-2.17%	-6.64%	-2.39%	3.28%	-3.83%	-2.99%	-1.09%	-4.45%	-3.44%	-6.05%	-6.46%	-2.87%
acre-feet	-1436	-1033	-4069	-2310	3532	-4184	-3636	-1188	-4208	-2675	-3180	-3909	-28295

Table 31: Monthly water volumes through the Crystal powerplant for Alternative C

Crystal Monthly Power Volume (Acre-Ft) Alt C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	42827	39213	42245	121806	130832	108287	109193	125240	112986	86259	42517	54492	1015897
1976	43133	39141	40463	86948	114129	90465	93973	90399	70251	53769	18480	20955	762106
1977	20023	19866	28403	80369	86766	91542	95221	85867	56587	44424	20666	24494	654228
1978	25216	25396	32918	114925	122289	126826	101381	98307	73748	70411	34329	25622	851367
1979	32945	70034	29311	117367	128292	124559	128389	110395	75228	56325	26992	25508	925345
1980	27478	30037	37840	106782	127503	124688	120443	123446	86443	77465	29190	31349	922666
1981	25249	37294	46669	76980	79118	74998	87152	86985	58514	52294	25299	19043	669596
1982	19398	19074	23950	59795	93017	102483	85344	74373	65474	65351	52172	58705	719137
1983	40301	36700	39554	104979	129374	124852	131535	132065	123863	116666	81848	108271	1170009
1984	130018	121629	123573	129933	130697	122102	126474	110114	93591	57173	57104	74770	1277178
1985	124872	94174	39057	112030	127672	123087	127369	125912	110377	92150	92180	113193	1282074
1986	108649	50554	124013	121480	127833	123374	114359	117355	85787	74817	62031	88260	1198512
1987	72137	53944	33382	110462	123767	125838	126190	119552	113037	90782	46684	57394	1073169
1988	34084	38257	32870	77687	111739	88486	111654	107385	62872	53638	18349	20343	757365
1989	19035	17079	18402	74053	103733	101216	112426	99784	83603	61968	21085	18427	730811
1990	20844	23502	34338	82220	78658	78942	100077	93433	64934	36214	18018	22037	653218
1991	24562	22318	25085	52934	117526	122433	125958	116029	95315	84146	43971	62211	892486
1992	33283	37808	33043	68360	100658	107369	122029	93285	84783	71276	30335	32354	814582
1993	35204	35278	122761	121378	131087	124556	127218	124957	111061	100537	69028	62749	1165814
1994	39303	35824	46813	76723	107337	99721	121636	87164	63520	45455	29011	32083	784592
1995	34689	23832	91443	119071	127449	124301	125347	127195	85382	51934	28590	35981	975215
1996	37256	88267	125351	121055	126977	107890	124554	96442	76368	54307	45065	66430	1069963
1997	124773	113388	101902	91097	127290	123425	119988	91139	88686	83414	78630	85221	1228953
1998	38174	35534	53149	94107	126408	108879	128213	106698	96397	74082	47711	58400	967752
1999	27429	30470	56652	80653	97467	110576	124472	111428	111335	100735	75306	82663	1009186
2000	47127	43806	58229	98981	102817	101351	125352	89345	69890	61956	18104	19810	836768
2001	28833	21612	42326	68573	101319	106594	125708	93133	99962	71872	29871	38235	828039
2002	29605	24391	31090	73729	85178	93650	100623	85470	56150	36514	18556	20436	655393
2003	25129	24424	29699	64693	102282	70548	114686	107227	63941	52285	18088	22607	695608
2004	23965	25580	26476	49878	100232	77965	107065	100493	72689	45244	18358	19002	666947
2005	18790	17293	22208	60424	82877	76366	119670	85124	80730	57670	31320	30835	683308
Average	43688	41797	51394	90951	111365	106044	115603	103734	83661	67133	39642	46190	901203
Difference from No Action													
percent	-7.38%	-12.31%	-16.08%	-5.84%	3.27%	-3.00%	-4.84%	-4.58%	-11.61%	-13.67%	-24.51%	-23.69%	-8.55%
acre-feet	-3482	-5865	-9846	-5644	3523	-3281	-5881	-4984	-10987	-10627	-12873	-14336	-84286

Table 32: Monthly water volumes through the Crystal powerplant for Alternative D

Crystal Monthly Power Volume (Acre-Ft) Alt D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1975	42827	39213	42245	121806	130832	108287	109193	125240	112986	86259	42517	54492	1015897
1976	43133	39141	40463	86948	114394	87419	106286	90271	70796	53769	18480	20955	772055
1977	20023	19866	28403	80369	86766	91542	95221	85867	56587	44424	20666	24494	654228
1978	25216	25396	32918	117124	126275	123958	84663	98997	73748	70411	34329	25622	838656
1979	32945	111216	78903	119838	128280	124909	111890	112921	77178	56325	26992	25508	1006907
1980	27656	101166	67388	120341	129064	124878	125728	125869	98203	79212	37229	49518	1086252
1981	37779	37050	48569	77883	79118	74998	87152	86985	58514	52294	25299	19043	684684
1982	24573	36754	24065	111914	127496	92118	117466	102743	100188	96483	87503	98590	1019892
1983	49142	43659	55517	104712	128603	124317	131234	131540	123564	116678	81865	108291	1199122
1984	129390	121041	123431	129702	130676	122086	128626	126531	121282	108076	115050	126481	1482372
1985	125402	94364	60587	120534	127616	123669	128971	127032	110811	92272	92318	113349	1316925
1986	108643	50557	125061	122565	128882	118087	128201	125543	117729	110341	103504	125653	1364765
1987	71057	54456	55771	112926	120640	125093	126034	119737	113241	90965	46892	57628	1094439
1988	34016	38290	32900	77749	89340	94908	125437	107893	63817	56648	18349	20343	759690
1989	22205	28474	45372	74249	82795	100555	125551	103916	93648	61968	21085	18427	778244
1990	20844	23502	34338	82220	78658	84677	110817	92216	64934	36214	18018	25543	671981
1991	30964	23698	32856	58776	120939	126389	127645	120159	99504	87788	48101	66874	943693
1992	34457	37754	35715	68565	87302	105363	127599	108549	99526	84507	45342	47628	882306
1993	34678	36194	124877	123479	132171	124670	128624	125622	117689	105349	77340	72132	1202826
1994	43928	39881	51305	80374	75666	117805	125644	94838	76397	61317	48473	55467	871095
1995	34304	24015	91645	120042	127529	124377	125601	127342	120784	115009	104424	121080	1236153
1996	58663	78451	120407	121912	127170	111160	125327	104180	84022	61176	52856	75225	1120549
1997	124781	113130	101778	93268	127096	125297	127735	120786	116268	109832	108509	119014	1387494
1998	53797	47129	66097	89987	122625	102300	125699	107251	96950	74579	48274	59036	993724
1999	27417	30476	56658	80772	97058	111402	126080	124080	117350	113676	89855	99072	1073896
2000	55387	51279	66217	95861	81276	107372	125952	92349	75973	67804	22030	30004	871505
2001	28833	21612	42326	68573	85879	118987	125953	98719	105385	76738	35391	44466	852862
2002	29276	24532	32770	75342	85178	93650	100623	85470	56150	36514	18556	20436	658498
2003	25129	24424	29699	64693	75920	70548	114757	107227	63941	52285	18088	22607	669317
2004	23965	25580	26476	49878	68825	75354	105938	100493	72689	45244	18358	19002	631803
2005	18790	17293	22208	90727	115494	85194	122657	89139	84642	61180	35068	34625	777016
Average	46426	47084	57967	94940	107728	107141	118655	108694	91758	76301	50347	58084	965124
Difference from No Action													
percent	-1.58%	-1.22%	-5.35%	-1.71%	-0.11%	-2.00%	-2.33%	-0.02%	-3.05%	-1.88%	-4.13%	-4.03%	-2.07%
acre-feet	-744	-579	-3274	-1655	-115	-2184	-2829	-24	-2891	-1459	-2168	-2442	-20365

Due to the smaller size of the powerplant at Crystal Reservoir, bypasses occur with a much greater frequency than at the other two Aspinall Unit reservoirs. Bypasses of the Crystal Powerplant occur when releases from the dam exceed 2150 cfs. Typically releases upstream at Morrow Point Dam are planned so that all water from Morrow Point can still be run through the powerplant at Crystal. However, spring runoff during wet or even average years can cause Aspinall Unit releases to increase to a point where the powerplant at Crystal must be bypassed.

Table 33: Number of days per year that water bypasses the powerplant at Crystal Reservoir

Crystal Bypasses Number of Days/Year					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	82	94	91	91	91
1976	1	15	20	26	20
1977	0	0	0	0	0
1978	69	73	64	76	64
1979	65	168	122	116	122
1980	87	117	104	117	104
1981	0	0	0	0	0
1982	51	27	73	32	73
1983	113	114	124	103	110
1984	280	283	280	141	215
1985	136	140	142	164	142
1986	137	131	129	130	129
1987	79	70	79	81	79
1988	17	5	8	18	8
1989	31	21	11	20	31
1990	0	0	0	0	0
1991	43	45	42	51	42
1992	2	1	11	20	2
1993	141	101	101	150	97
1994	42	42	39	23	41
1995	148	156	155	139	148
1996	91	103	107	99	80
1997	117	108	130	99	130
1998	16	15	35	29	35
1999	70	74	67	54	45
2000	30	28	18	22	3
2001	48	47	47	30	19
2002	0	0	0	0	0
2003	0	7	11	18	5
2004	0	0	6	16	0
2005	31	27	21	1	24

Table 33 shows the number of days per year that water was released through the bypass tubes at Crystal Reservoir for the No Action Alternative and Alternatives A, B, C and D.

Spillway usage at Crystal Reservoir primarily occurs during wetter hydrologic periods. Even though the combined poweplant and bypass tube capacity is only 4,150 cfs, which is less than the capacity of the upstream powerplant at Morrow Point, spillway usage at Crystal can generally be avoided with prudent operation of the Aspinall Unit reservoirs. Targets specified in the Flow Recommendations for average and wetter years will usually necessitate usage of the spillway at Crystal Dam. On rare occasions when downstream tributary flows are large enough to supply sufficient water to the Gunnison River, spillway usage at Crystal may not be needed to reach spring peak flow targets. However, the spring peak flow targets are high enough that it will typically take releases from the Aspinall Unit that will require spilling water at Crystal Reservoir. When inflows to Crystal Reservoir exceed 4,150 cfs water will go over the spillway.

Table 34: Number of days per year that water is spilled from Crystal Reservoir

Crystal Spills Number of Days/Year					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	7	21	21	21
1976	0	6	11	17	11
1977	0	0	0	0	0
1978	0	0	16	27	16
1979	0	8	26	58	26
1980	0	11	16	47	16
1981	0	0	0	0	0
1982	0	7	16	18	16
1983	24	27	28	28	29
1984	78	76	78	103	78
1985	26	36	38	38	38
1986	15	26	24	48	24
1987	16	16	16	21	16
1988	0	0	0	1	0
1989	0	0	1	8	0
1990	0	0	0	0	0
1991	4	7	8	13	8
1992	0	0	0	10	0
1993	20	43	38	43	37
1994	0	0	2	12	0
1995	64	79	80	104	80
1996	0	12	22	27	22
1997	24	31	28	48	28
1998	0	5	2	4	2
1999	7	5	14	19	11
2000	0	0	8	3	0
2001	0	0	6	2	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0

The Gunnison River flows into Black Canyon National Park a few miles below Crystal Reservoir. As such, flows in the canyon are directly influenced by releases at Crystal Reservoir. Attempts to meet spring flow targets in the Gunnison River at the Whitewater Gage will provide some benefit to the resources of the Black Canyon.

Table 35 shows peak flows in the Black Canyon, occurring in the month of May, as measured at the gage just downstream of the Gunnison Tunnel diversion dam. All action alternatives provide some level of spring peaks with greater magnitude and more frequency than the No Action Alternative.

Table 35: Peak flows in the Black Canyon occurring during the month of May

Gunnison River - Black Canyon May Peak Flow (cfs)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	3323	6341	6839	6839	6839
1976	396	5129	4387	4984	4387
1977	450	476	476	476	476
1978	3602	3602	6051	6058	6051
1979	3655	5515	5071	4837	5071
1980	3564	6376	6253	6178	6253
1981	354	354	354	354	354
1982	3559	4935	6451	6054	6451
1983	3490	4496	2831	2831	4909
1984	4827	6429	4827	4827	4827
1985	3781	5800	7339	7449	7360
1986	3441	5108	6759	6712	6763
1987	3121	3549	3523	4249	3523
1988	355	1341	2921	3462	1341
1989	299	1793	3314	3732	299
1990	299	299	299	299	299
1991	3519	4177	4720	4706	4687
1992	653	642	3330	3940	642
1993	3681	5244	4458	4579	4471
1994	342	340	4167	4964	344
1995	3788	6690	6991	6991	6991
1996	3204	5209	8475	8775	8518
1997	3565	5388	7274	7366	7274
1998	3364	4803	3843	3940	3844
1999	435	4955	4944	5225	4944
2000	471	471	6204	4248	483
2001	1660	1660	5537	4089	1660
2002	439	476	476	476	476
2003	951	1793	2863	2863	1295
2004	299	299	2863	2990	299
2005	3527	3480	1535	1476	3533

Table 36 contains peak flows in the Black Canyon, occurring in the months of June or July. Annual peak flows in the Black Canyon are divided into these two categories because of how operations at the Aspinall Unit dictate the timing of spring peak flows. Typically when the annual peak occurs during the month of May, this is a result of

operational releases from the Aspinall Unit intended to create a spring peak in the lower Gunnison River. When the annual peak occurs during the months of June or July this is usually a result of very wet hydrologic conditions that have caused the Aspinall Unit reservoirs to fill completely and spill excess water that cannot be stored.

Table 36: Peak flows in the Black Canyon occurring during the months of June or July

Gunnison River - Black Canyon June-July Peak Flow (cfs)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	3320	3311	4506	4506	4506
1976	1293	895	1157	3487	1157
1977	438	806	806	806	806
1978	1739	1644	4430	5600	4430
1979	3646	4189	6684	7069	6684
1980	3190	2836	5299	6482	5299
1981	438	753	753	753	753
1982	2869	2146	4025	4428	4025
1983	10750	10081	10707	11212	9613
1984	10990	11076	10458	10906	10444
1985	11743	11564	9063	9248	9081
1986	5028	5652	6782	7062	6782
1987	5856	6611	6346	5955	6346
1988	1042	1038	918	1072	1038
1989	1051	1051	1003	3498	1051
1990	699	793	903	896	823
1991	4144	4446	3600	4848	3585
1992	1382	1212	2000	4350	1352
1993	5666	7573	7587	7596	7588
1994	1944	1946	1146	2908	1943
1995	12156	11750	11871	12560	11876
1996	2200	4114	5840	5989	5849
1997	7682	7462	7808	7994	7808
1998	1910	1614	1885	3408	1884
1999	3991	2791	5093	5673	4757
2000	1140	1227	3602	1626	1316
2001	1572	1572	1224	1164	1572
2002	438	858	858	858	858
2003	671	1242	1242	1242	1242
2004	840	911	981	1334	859
2005	1147	1134	1147	1074	1181

The total annual volume of water through the Black Canyon will not change under alternatives considered. Higher spring peak flows will result in lower flows at other times of the year. Tables 37-41 show average monthly flows for No Action and Action Alternatives for the study period.

Table 37: Average monthly flows for the Gunnison River in the Black Canyon for the No Action Alternative

Gunnison River - Black Canyon Average Monthly Flow (cfs)												
					No Action							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	428	415	707	2191	3062	1505	1567	1181	1106	835	791	1007
1976	685	689	547	601	342	777	1166	526	578	504	496	365
1977	327	336	394	448	421	425	423	427	434	309	331	371
1978	387	384	424	1543	1822	1654	1143	827	571	398	334	418
1979	1179	2130	2142	2227	2647	1917	1346	1024	907	671	652	759
1980	520	2004	1356	2089	2958	2220	1157	996	781	699	762	976
1981	601	479	472	380	300	352	359	388	303	299	300	306
1982	483	734	353	1413	2342	1283	1247	876	1160	1350	1582	1723
1983	875	859	859	1149	1782	4239	4011	1769	1197	1280	1378	1763
1984	2150	2150	2018	3044	4322	7328	4685	1563	1335	1464	2029	2384
1985	2105	1699	985	1972	2885	6257	1932	1093	1078	1131	1575	1869
1986	1766	911	2117	1604	2469	2146	3244	1042	1207	1370	1760	2215
1987	1156	980	866	1083	1710	3546	1165	922	946	817	804	954
1988	515	680	514	595	324	533	1023	498	361	386	309	334
1989	385	536	764	346	298	626	1024	474	502	299	300	300
1990	322	373	401	354	298	443	685	362	313	299	370	496
1991	518	440	504	658	1934	2231	1215	1057	1017	946	837	1119
1992	543	539	539	855	545	857	1171	806	837	784	737	774
1993	486	682	2002	2519	3447	4049	2145	1152	1166	1107	1195	1164
1994	706	704	704	590	318	1166	1140	558	517	559	811	896
1995	554	423	1392	2048	3455	5573	7889	1661	1239	1413	1678	1972
1996	953	1355	1819	1841	2687	1556	1177	868	727	712	1033	1402
1997	2131	2118	1618	1420	2637	4682	1942	1127	1277	1332	1818	1931
1998	873	843	842	945	1983	762	1154	734	728	604	788	935
1999	440	527	698	369	430	2146	1535	1216	1365	1458	1561	1675
2000	932	920	919	791	393	758	1126	460	410	469	375	492
2001	462	380	512	345	485	1140	1153	614	832	636	589	717
2002	464	432	390	370	391	409	438	436	335	299	301	303
2003	351	372	387	354	357	354	438	438	331	299	301	329
2004	358	395	349	299	298	489	813	386	317	299	300	300
2005	300	885	582	995	1570	573	1098	533	532	420	611	589
	773	851	909	1143	1578	2000	1633	839	787	756	861	995

Table 38: Average monthly flows for the Gunnison River in the Black Canyon for the Alternative A

Gunnison River - Black Canyon Average Monthly Flow (cfs)												
					Alt A							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	697	706	670	1400	2632	1703	1965	1181	1130	855	815	1033
1976	696	683	592	594	1682	518	881	513	368	321	311	341
1977	326	349	419	473	422	561	565	477	458	327	337	398
1978	410	457	435	1200	1604	1503	1126	811	556	618	498	418
1979	1016	2119	2142	1827	2727	1929	1349	1049	911	674	656	763
1980	530	2005	1345	1427	3116	2362	1323	1198	811	830	682	876
1981	612	664	464	370	300	390	400	397	303	299	300	310
1982	388	652	299	1230	2528	1210	1251	882	1167	1355	1588	1730
1983	879	862	862	1148	1836	4394	3822	1756	1197	1280	1377	1763
1984	2150	2150	2018	3048	4475	7130	4752	1552	1310	1464	2029	2384
1985	2105	1699	986	1833	3205	6159	1854	1158	1066	1112	1553	1845
1986	1767	910	2117	1236	2556	2346	3345	1041	1204	1360	1749	2203
1987	1156	981	861	1082	1770	3552	1179	909	933	806	790	940
1988	549	663	536	580	397	521	1001	604	318	348	306	323
1989	356	510	738	345	462	610	1024	501	455	299	300	300
1990	339	423	406	354	298	427	639	504	301	299	300	379
1991	489	418	476	658	1823	2329	1217	1059	1019	948	839	1121
1992	576	653	540	818	505	818	1171	801	832	779	731	767
1993	559	646	1999	1686	3047	5193	2237	1152	1158	1099	1186	1155
1994	702	700	700	587	317	1174	1140	563	518	560	812	897
1995	554	423	1392	1609	3285	6179	8118	1504	1239	1398	1643	1955
1996	940	1362	1825	1267	2515	2068	1246	901	760	742	1068	1440
1997	2132	2117	1618	1428	2896	4427	1923	1130	1277	1332	1817	1930
1998	872	842	842	945	2141	715	1145	713	706	585	766	911
1999	440	545	681	364	1527	1254	1396	1161	1362	1449	1551	1664
2000	926	914	914	793	395	778	1126	498	398	459	363	479
2001	462	380	512	345	485	1140	1153	614	832	636	589	717
2002	464	432	393	370	393	575	637	447	335	299	301	322
2003	399	431	398	368	520	384	874	746	318	299	301	348
2004	382	434	346	299	298	328	697	587	309	299	300	303
2005	300	304	299	827	1254	519	1089	518	516	406	596	571
	780	853	898	984	1658	2039	1666	869	776	759	853	987

Table 39: Average monthly flows for the Gunnison River in the Black Canyon for the Alternative B

Gunnison River - Black Canyon Average Monthly Flow (cfs)												
					Alt B							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	697	706	670	1400	3309	2361	1173	1181	998	741	681	886
1976	701	680	570	560	2148	500	746	481	313	299	311	341
1977	326	349	419	473	422	561	565	477	458	327	337	398
1978	410	457	435	1187	2757	3014	448	600	391	627	488	417
1979	536	2103	1276	1787	2495	4167	1427	872	391	309	340	415
1980	450	1759	1061	1392	3403	2425	1172	1195	782	814	626	805
1981	614	667	441	357	300	390	400	397	303	299	300	310
1982	400	662	301	1231	2858	1662	1081	763	1047	1242	1471	1603
1983	799	786	786	1178	1806	4652	3891	1726	1197	1264	1357	1741
1984	2150	2150	2018	3044	4324	7329	4707	1560	1310	1464	2030	2385
1985	2105	1699	986	1833	3480	6068	1667	1158	1066	1111	1551	1843
1986	1767	910	2117	1236	2809	3608	1913	1034	1201	1352	1739	2192
1987	1156	981	855	1082	1944	3396	1175	906	930	804	788	937
1988	549	663	534	580	797	475	881	600	302	299	306	323
1989	305	451	679	344	1008	553	922	463	372	299	300	300
1990	339	423	406	354	298	392	572	500	301	299	300	355
1991	443	392	410	658	2276	2065	1196	1023	978	918	803	1082
1992	560	650	518	818	1081	802	1171	699	726	687	624	650
1993	557	649	1999	1686	2925	5337	2189	1152	1166	1106	1194	1163
1994	706	704	704	590	1294	667	1140	485	411	467	703	778
1995	559	421	1389	1586	4007	5482	7872	1672	1239	1410	1674	1967
1996	951	1356	1820	1267	4069	1594	1149	704	557	564	860	1213
1997	2128	2119	1620	1376	3281	4177	1833	1123	1277	1332	1817	1930
1998	872	842	842	945	1873	772	1162	752	747	620	807	956
1999	439	545	682	372	1716	1826	1172	988	1330	1356	1441	1548
2000	867	857	857	816	1653	1046	805	439	299	299	300	300
2001	302	321	335	325	1806	658	1153	428	643	472	396	507
2002	471	428	359	333	393	575	637	447	335	299	301	322
2003	399	431	398	368	819	384	874	746	318	299	301	348
2004	382	434	346	299	760	324	703	587	309	299	300	303
2005	300	304	299	637	688	515	1096	529	527	416	606	584
	750	836	843	971	2026	2186	1513	829	717	713	808	932

Table 40: Average monthly flows for the Gunnison River in the Black Canyon for the Alternative C

Gunnison River - Black Canyon Average Monthly Flow (cfs)												
					Alt C							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	697	706	670	1400	3309	2361	1173	1181	998	741	681	886
1976	701	680	570	560	2530	799	546	483	304	299	311	341
1977	326	349	419	473	422	561	565	477	458	327	337	398
1978	410	457	435	1145	2658	3912	1202	588	391	627	488	417
1979	536	1261	469	1728	2397	5478	4552	856	359	309	340	415
1980	447	522	580	1159	2956	5024	2403	1252	587	788	491	510
1981	411	672	411	342	300	390	400	397	303	299	300	310
1982	315	343	299	299	1746	2400	498	302	464	735	877	955
1983	655	661	526	1184	1912	5027	3877	1738	1197	1279	1375	1761
1984	2150	2150	2018	3048	4309	7306	6713	3179	734	629	960	1216
1985	2112	1696	635	1682	3539	6604	1588	1158	1064	1109	1549	1841
1986	1767	910	2117	1236	2818	5842	2577	779	644	755	1042	1435
1987	1173	971	491	1023	2487	3290	1163	903	927	801	785	933
1988	550	663	534	579	1581	417	695	596	302	299	306	323
1989	305	305	299	342	1450	933	699	450	319	299	300	300
1990	339	423	406	354	298	342	492	521	301	299	300	355
1991	396	399	361	559	2206	2252	1184	953	906	857	732	1004
1992	540	654	473	814	1184	1659	1005	553	585	564	480	520
1993	568	629	1997	1686	2945	5350	2748	1072	1033	991	1060	1016
1994	634	634	633	531	2371	833	972	435	298	299	482	513
1995	560	420	1388	1581	4091	5511	8100	5660	561	370	397	581
1996	601	1527	1952	1237	4105	2357	1095	578	428	453	729	1070
1997	2124	2121	1622	1339	3280	6089	2518	571	786	902	1314	1381
1998	618	634	631	1014	2038	1265	1158	744	737	612	798	945
1999	440	545	682	370	1761	2681	1121	826	1220	1192	1250	1340
2000	762	756	755	857	1333	733	1100	452	299	366	300	316
2001	462	380	512	345	1252	815	1153	523	741	557	496	616
2002	469	429	365	343	393	575	637	447	335	299	301	322
2003	399	431	398	368	1208	384	874	746	318	299	301	348
2004	382	434	346	299	1422	388	703	587	309	299	300	303
2005	300	304	299	343	501	400	978	447	444	343	526	501
	714	744	751	911	2090	2644	1758	950	592	581	642	747

Table 41: Average monthly flows for the Gunnison River in the Black Canyon for the Alternative D

Gunnison River - Black Canyon Average Monthly Flow (cfs)												
					Alt D							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	697	706	670	1400	3309	2361	1173	1181	998	741	681	886
1976	701	680	570	560	2148	500	746	481	313	299	311	341
1977	326	349	419	473	422	561	565	477	458	327	337	398
1978	410	457	435	1187	2757	3014	448	600	391	627	488	417
1979	536	2103	1276	1787	2495	4167	1427	872	391	309	340	415
1980	450	1759	1061	1392	3403	2425	1172	1195	782	814	626	805
1981	614	667	441	357	300	390	400	397	303	299	300	310
1982	400	662	301	1231	2858	1662	1081	763	1047	1242	1471	1603
1983	799	786	786	1178	2251	4155	3872	1741	1197	1279	1376	1761
1984	2150	2150	2018	3048	4310	7329	4725	1542	1310	1464	2029	2384
1985	2105	1699	985	1833	3489	6065	1664	1158	1066	1111	1551	1843
1986	1767	910	2117	1236	2808	3608	1913	1034	1201	1352	1739	2192
1987	1156	981	855	1082	1944	3396	1175	906	930	804	788	937
1988	549	663	534	580	397	521	1002	604	318	348	306	323
1989	357	510	738	345	298	626	1024	517	488	299	300	300
1990	339	423	406	354	298	438	667	501	301	299	300	412
1991	501	424	488	658	2272	2083	1196	1021	977	916	802	1080
1992	559	653	517	818	518	843	1171	802	833	779	732	768
1993	559	646	1999	1686	2928	5310	2193	1153	1171	1110	1199	1169
1994	709	707	706	592	319	1162	1140	560	515	557	809	894
1995	554	423	1392	1608	4005	5468	7888	1656	1239	1409	1672	1965
1996	950	1356	1821	1267	4065	1596	1149	704	557	565	860	1213
1997	2128	2119	1620	1376	3281	4177	1833	1123	1277	1332	1817	1930
1998	872	842	842	945	1873	772	1162	752	747	620	807	956
1999	439	545	682	372	1716	1576	1193	1037	1346	1403	1495	1607
2000	897	886	885	805	407	828	1126	501	401	461	366	482
2001	462	380	512	345	485	1140	1153	614	832	636	589	717
2002	464	432	393	370	393	575	637	447	335	299	301	322
2003	399	431	398	368	430	384	874	746	318	299	301	348
2004	382	434	346	299	298	337	684	587	309	299	300	303
2005	300	304	299	852	1328	551	1083	512	510	400	589	563
	759	842	855	981	1865	2194	1533	845	737	732	825	956

Recreational and fishery values are affected by various flow levels in the Black Canyon and downstream Gunnison Gorge. Tables 42 through 53 present various flow data for the No Action and Action Alternatives.

Table 42: Number of days in the Gunnison River in the Black Canyon with flows between 400 cfs and 1,200 cfs from May through September

Gunnison River in Black Canyon Days 400-1200 cfs May-Sep					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	89	82	100	100	100
1976	113	75	72	56	72
1977	136	131	131	131	131
1978	96	108	68	57	68
1979	78	78	59	29	59
1980	87	75	77	48	77
1981	42	40	40	40	40
1982	96	98	109	47	109
1983	31	31	31	31	31
1984	9	10	9	43	10
1985	61	56	56	68	56
1986	44	48	59	77	59
1987	100	100	101	99	101
1988	78	80	77	77	80
1989	110	112	71	71	110
1990	61	72	72	53	72
1991	109	106	110	114	110
1992	144	145	136	133	144
1993	71	74	71	76	61
1994	109	109	115	68	109
1995	29	30	29	30	30
1996	101	105	122	113	122
1997	28	27	27	77	27
1998	123	123	123	116	123
1999	73	75	98	99	91
2000	132	102	78	79	125
2001	111	111	111	122	111
2002	110	109	109	109	109
2003	80	78	78	74	78
2004	68	63	67	67	65
2005	141	143	151	111	142
Average	85.8	83.7	82.5	77.9	84.6

Table 43: Number of days in the Gunnison River in the Black Canyon with flows exceeding 3,000 cfs from May through September

Gunnison River in Black Canyon Days > 3000 cfs May-Sep					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	20	13	31	31	31
1976	0	7	12	18	12
1977	0	0	0	0	0
1978	5	4	32	42	32
1979	11	11	34	64	34
1980	15	17	22	52	22
1981	0	0	0	0	0
1982	12	11	21	24	21
1983	44	40	36	41	40
1984	80	80	80	106	81
1985	41	41	40	40	40
1986	31	32	29	50	29
1987	20	22	24	31	24
1988	0	0	0	5	0
1989	0	0	2	11	0
1990	0	0	0	0	0
1991	13	13	14	18	14
1992	0	0	3	13	0
1993	68	55	56	61	55
1994	0	0	4	14	0
1995	94	82	83	106	83
1996	17	15	23	28	23
1997	40	38	33	50	33
1998	9	8	4	9	4
1999	11	7	15	22	13
2000	0	0	9	4	0
2001	0	0	8	4	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	3	1	0	0	2
Average	17.2	16.0	19.8	27.2	19.1

Table 44: Number of days in the Gunnison River in the Black Canyon with flows exceeding 3,000 cfs during the month of June

Gunnison River in Black Canyon Days > 3000 cfs June					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	1	0	13	13	13
1976	0	0	0	2	0
1977	0	0	0	0	0
1978	0	0	18	25	18
1979	3	3	21	30	21
1980	2	0	5	30	5
1981	0	0	0	0	0
1982	0	0	9	15	9
1983	17	17	17	20	13
1984	30	30	30	30	30
1985	30	30	30	30	30
1986	5	6	20	30	20
1987	18	18	17	15	17
1988	0	0	0	0	0
1989	0	0	0	2	0
1990	0	0	0	0	0
1991	6	8	2	7	2
1992	0	0	0	8	0
1993	30	30	30	30	30
1994	0	0	0	0	0
1995	30	30	30	30	30
1996	0	5	5	10	5
1997	25	23	20	30	20
1998	0	0	0	4	0
1999	11	0	6	13	4
2000	0	0	2	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0
Average	6.7	6.5	8.9	12.1	8.6

Table 45: Number of days in the Gunnison River in the Black Canyon with flows between 500 cfs and 1,000 cfs from May through September

Gunnison River in Black Canyon Days 500-1000 cfs May-Sep					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	19	2	45	45	45
1976	80	70	65	43	65
1977	0	55	55	55	55
1978	67	75	47	48	47
1979	30	30	41	18	41
1980	61	29	28	27	28
1981	0	17	17	17	17
1982	38	38	41	12	41
1983	0	0	0	0	0
1984	0	0	0	32	0
1985	0	0	0	0	0
1986	0	0	5	72	5
1987	71	71	72	61	72
1988	44	53	73	55	53
1989	28	31	55	57	33
1990	48	56	48	31	56
1991	4	2	33	67	33
1992	95	97	91	108	95
1993	0	0	0	0	0
1994	73	73	24	41	73
1995	0	0	0	30	0
1996	61	66	78	49	78
1997	0	0	0	77	0
1998	90	91	90	83	90
1999	2	5	42	48	8
2000	25	33	57	43	32
2001	78	78	49	89	78
2002	0	50	50	50	50
2003	6	65	64	61	64
2004	47	53	54	55	54
2005	89	105	94	22	102
Average	34.1	40.2	42.5	45.0	42.4

Table 46: Number of days in the Gunnison River in the Black Canyon with flows less than 400 cfs from May through September

Gunnison River in Black Canyon Days < 400 cfs May-Sep					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	1	1	1
1976	39	63	61	71	61
1977	17	22	22	22	22
1978	0	0	37	37	37
1979	0	0	18	27	18
1980	0	0	0	15	0
1981	111	113	113	113	113
1982	0	0	0	74	0
1983	0	0	0	0	0
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	0	2	0
1987	0	0	0	0	0
1988	75	72	68	59	72
1989	43	38	72	63	43
1990	92	81	81	100	81
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	0	0	0	0	0
1994	32	32	26	62	32
1995	0	0	0	0	0
1996	0	0	0	4	0
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	4	9	1	1	4
2000	21	50	57	61	26
2001	25	25	25	19	25
2002	43	44	44	44	44
2003	73	70	65	62	72
2004	85	90	78	69	88
2005	0	0	0	39	0
Average	21.3	22.9	24.8	30.5	23.8

Table 47: Number of days in the Gunnison River in the Black Canyon with flows at 300 cfs from May through October

Gunnison River in Black Canyon Days at 300 cfs May-Oct					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	1	1	1
1976	25	17	62	60	62
1977	30	31	31	31	31
1978	0	3	33	33	33
1979	0	0	25	48	25
1980	0	0	0	11	0
1981	128	131	131	131	131
1982	0	0	0	65	0
1983	0	0	0	0	0
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	0	0	0
1987	0	0	0	0	0
1988	31	57	79	72	57
1989	74	69	63	83	74
1990	111	103	102	108	104
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	0	0	0	0	0
1994	17	17	11	85	17
1995	0	0	0	0	0
1996	0	0	0	0	0
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	4	9	1	0	3
2000	0	0	68	30	0
2001	25	25	25	17	25
2002	64	64	64	64	64
2003	98	94	89	86	96
2004	108	111	104	95	104
2005	0	0	0	32	0
Average	23.1	23.6	28.7	33.9	26.7

Table 48: Number of days in the Gunnison River in the Black Canyon with flows less than 600 cfs from May through October

Gunnison River in Black Canyon Days < 600 cfs May-Oct					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	4	4	4
1976	131	122	128	151	128
1977	184	154	154	154	154
1978	61	40	75	71	75
1979	0	0	70	66	70
1980	0	5	6	33	6
1981	184	178	178	178	178
1982	0	0	16	110	16
1983	0	0	0	0	0
1984	0	0	0	28	0
1985	0	0	0	0	0
1986	0	0	3	12	3
1987	0	0	0	0	0
1988	137	115	115	116	115
1989	136	131	117	132	128
1990	152	154	173	171	145
1991	0	0	0	0	0
1992	24	31	18	93	24
1993	0	0	0	0	0
1994	122	122	119	109	122
1995	0	0	0	60	0
1996	0	0	54	102	54
1997	0	0	0	24	0
1998	17	17	17	17	17
1999	35	28	27	29	22
2000	130	127	113	114	120
2001	43	43	87	83	43
2002	184	143	143	143	143
2003	179	119	114	109	121
2004	137	148	138	129	148
2005	112	121	127	143	119
Average	63.5	58.0	64.4	76.8	63.1

Table 49: Number of days in the Gunnison River in the Black Canyon with flows between 600 cfs and 900 cfs from May through October

Gunnison River in Black Canyon Days 600-900 cfs May-Oct					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	22	17	41	41	41
1976	3	46	35	6	35
1977	0	30	30	30	30
1978	36	66	47	49	47
1979	31	31	31	11	31
1980	61	43	41	29	41
1981	0	6	6	6	6
1982	31	31	38	36	38
1983	0	0	0	0	0
1984	0	0	0	45	0
1985	0	0	0	0	0
1986	0	0	1	94	1
1987	31	31	31	31	31
1988	16	36	54	50	36
1989	17	18	35	32	25
1990	32	30	10	13	39
1991	18	17	17	20	17
1992	109	102	114	38	109
1993	0	0	0	7	0
1994	2	2	12	21	2
1995	0	0	0	0	0
1996	91	84	53	4	53
1997	0	0	0	70	0
1998	104	105	104	97	104
1999	1	2	2	31	7
2000	6	9	53	26	14
2001	75	75	40	40	75
2002	0	41	41	41	41
2003	4	40	41	39	41
2004	47	35	34	33	36
2005	10	21	20	12	20
Average	24.1	29.6	30.0	30.7	29.7

Table 50: Number of days in the Gunnison River in the Black Canyon with flows between 900 cfs and 1,500 cfs from May through October

Gunnison River in Black Canyon Days 900-1500 cfs May-Oct					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	101	113	92	92	92
1976	50	3	2	3	2
1977	0	0	0	0	0
1978	44	50	15	7	15
1979	86	96	24	27	24
1980	61	78	85	45	85
1981	0	0	0	0	0
1982	114	112	97	8	97
1983	91	92	89	88	90
1984	64	66	66	1	67
1985	92	106	106	107	107
1986	85	88	97	11	97
1987	104	103	104	100	104
1988	31	33	9	3	33
1989	31	34	23	2	31
1990	0	0	1	0	0
1991	130	130	129	130	128
1992	51	51	43	35	51
1993	107	108	109	103	109
1994	55	55	42	33	55
1995	73	87	85	12	83
1996	44	58	47	43	47
1997	106	105	105	15	105
1998	47	47	48	48	48
1999	90	95	116	96	114
2000	48	48	2	33	50
2001	60	60	42	50	60
2002	0	0	0	0	0
2003	1	24	23	23	22
2004	0	1	6	7	0
2005	52	34	35	29	36
Average	58.6	60.5	53.0	37.1	56.5

Table 51: Number of days in the Gunnison River in the Black Canyon with flows between 1,500 cfs and 3,000 cfs from May through October

Gunnison River in Black Canyon Days 1500-3000 cfs May-Oct					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	41	41	16	16	16
1976	0	6	7	6	7
1977	0	0	0	0	0
1978	38	24	15	15	15
1979	56	46	25	16	25
1980	47	41	30	25	30
1981	0	0	0	0	0
1982	27	30	12	6	12
1983	49	52	59	55	54
1984	40	38	38	4	36
1985	51	37	38	37	37
1986	68	64	54	17	54
1987	29	28	25	22	25
1988	0	0	6	10	0
1989	0	1	7	7	0
1990	0	0	0	0	0
1991	23	24	24	16	25
1992	0	0	6	5	0
1993	9	21	19	13	20
1994	5	5	7	7	5
1995	17	15	16	6	18
1996	32	27	7	7	7
1997	38	41	46	25	46
1998	7	7	11	13	11
1999	47	52	24	6	28
2000	0	0	7	7	0
2001	6	6	7	7	6
2002	0	0	0	0	0
2003	0	1	6	13	0
2004	0	0	6	15	0
2005	7	7	2	0	7
Average	20.5	19.8	16.8	12.1	15.6

Table 52: Number of days in the Gunnison River in the Black Canyon with flows between 3,000 cfs and 5,000 cfs from May through October

Gunnison River in Black Canyon Days 3000-5000 cfs May-Oct					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	20	10	25	25	25
1976	0	6	12	18	12
1977	0	0	0	0	0
1978	5	4	28	34	28
1979	11	6	20	23	20
1980	15	10	10	20	10
1981	0	0	0	0	0
1982	12	11	16	21	16
1983	28	22	17	22	22
1984	39	40	39	38	39
1985	21	15	12	13	12
1986	30	27	15	10	15
1987	16	17	21	29	21
1988	0	0	0	5	0
1989	0	0	2	11	0
1990	0	0	0	0	0
1991	13	13	14	18	14
1992	0	0	3	13	0
1993	62	35	38	36	40
1994	0	0	4	14	0
1995	61	35	31	25	38
1996	17	11	6	6	6
1997	26	21	16	13	16
1998	9	8	4	9	4
1999	11	7	13	13	13
2000	0	0	6	4	0
2001	0	0	6	4	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	3	1	0	0	2
Average	12.9	9.6	11.5	13.7	11.4

Table 53: Number of days in the Gunnison River in the Black Canyon with flows greater than 5,000 cfs from May through October

Gunnison River in Black Canyon Days > 5000 cfs May-Oct					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	3	6	6	6
1976	0	1	0	0	0
1977	0	0	0	0	0
1978	0	0	4	8	4
1979	0	5	14	41	14
1980	0	7	12	32	12
1981	0	0	0	0	0
1982	0	0	5	3	5
1983	16	18	19	19	18
1984	41	40	41	68	42
1985	20	26	28	27	28
1986	1	5	14	40	14
1987	4	5	3	2	3
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	6	20	18	25	15
1994	0	0	0	0	0
1995	33	47	52	81	45
1996	0	4	17	22	17
1997	14	17	17	37	17
1998	0	0	0	0	0
1999	0	0	2	9	0
2000	0	0	3	0	0
2001	0	0	2	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0
Average	4.4	6.4	8.3	13.5	7.7

The city of Delta is located on the banks of the Gunnison River downstream of the confluence of the mainstem of the Gunnison River with the North Fork of the Gunnison River. The city's proximity to the river gives it the highest potential for flood damage along the entire stretch of the mainstem Gunnison River downstream of the Aspinall Unit to the confluence with the Colorado River at Grand Junction.

Operations of the Aspinall Unit to create or enhance the spring peak on the Gunnison River at the Whitewater gage have a direct impact on the potential for flooding in the city of Delta. Table 54 shows the peak flow in the Gunnison River occurring during the month of May as measured at the gage at Delta. Annual spring peaks that occur during May are typically enhanced by releases from the Aspinall Unit. These releases are intended to coincide with the annual peak on the North Fork of the Gunnison River in

order to achieve the spring peak flow targets at the Whitewater gage with using minimal amounts of storage from Blue Mesa Reservoir.

Table 54: Peak flows in the Gunnison River occurring during the month of May as measured at the gage at Delta

Gunnison River @ Delta May Peak Flow (cfs)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	7019	9828	10308	10308	10308
1976	3889	7281	6649	6754	6649
1977	900	895	895	895	895
1978	8964	8964	9677	9423	9677
1979	11153	12935	12144	11922	12144
1980	12722	15100	15047	14488	15047
1981	2651	2651	2651	2651	2651
1982	6807	8006	9374	8664	9374
1983	13364	14034	12712	12712	12712
1984	16421	16386	16421	16421	16421
1985	9655	11542	13047	13237	13098
1986	8744	10338	11878	11887	11878
1987	7503	8074	7596	8214	7596
1988	2133	2723	4536	4754	2723
1989	1988	3146	4879	5081	1988
1990	1456	1456	1456	1456	1456
1991	6939	7461	7119	7040	7104
1992	4101	4111	6647	6740	4108
1993	15696	17260	16146	16338	16176
1994	3294	3292	6282	6538	3295
1995	10805	11924	12919	12920	12919
1996	7291	9136	11931	12202	11959
1997	9475	11256	12145	12085	12146
1998	8281	8454	7396	7551	7396
1999	3284	7091	7100	7497	7100
2000	2872	2875	7122	5588	2891
2001	2950	2950	6910	5956	2950
2002	842	842	842	842	842
2003	4499	4499	6144	6421	4499
2004	2390	2390	4451	4728	2390
2005	10278	10021	7603	7771	10070

Table 55 shows the peak flows in the Gunnison River that occur during the months of June or July. Annual peak flows that occur during the months of June or July are typically products of wet years where Blue Mesa Reservoir has filled and the spillways are in use at the Aspinall Unit reservoirs.

Table 55: Annual peak flows in the Gunnison River occurring during the months of June or July as measured at the gage at Delta

Gunnison River @ Delta June-July Peak Flow (cfs)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	6055	5964	7388	7388	7388
1976	2377	1887	2598	4900	2598
1977	689	876	876	876	876
1978	5784	5688	7752	7803	7752
1979	7759	8500	10433	11343	10433
1980	8521	8334	10817	12266	10817
1981	1775	1775	1775	1775	1775
1982	5768	5026	6950	7062	6950
1983	18507	17586	18413	16710	17146
1984	17922	17843	17923	17898	17921
1985	17209	16908	13956	13999	13955
1986	8343	8444	12406	12713	12405
1987	8194	9137	9015	8381	9015
1988	1951	1951	1951	2187	1951
1989	1622	1622	1484	4519	1622
1990	1602	1602	1602	1602	1602
1991	5589	5908	5182	6117	5168
1992	2476	2441	4180	6136	2453
1993	10824	12001	11997	11994	11997
1994	3177	3186	2153	4897	3172
1995	16522	15951	16471	16526	16474
1996	3331	4796	6834	7489	6841
1997	10224	9805	12754	13699	12755
1998	5567	5283	5541	6973	5541
1999	5350	4161	6970	7277	6601
2000	1946	2042	5087	3087	2152
2001	2807	2807	2649	1757	2807
2002	690	816	816	816	816
2003	3894	3894	3894	3894	3894
2004	1599	1599	1599	2143	1599
2005	4305	4195	4840	4785	4884

While the magnitude of spring peak flows is the first indicator of potential flood damage, another important parameter to analyze is the duration of high flows. Extended periods of high flows can significantly increase damages if flooding is occurring. Table 56 shows the number of days per year that flows in the Gunnison River as measured at the gage at Delta exceeded 15,000 cfs. Flows of this magnitude may cause fairly significant flooding within the city of Delta and in lands near the river outside of the city.

Table 56: Number of days per year that flows in the Gunnison River exceeded 15,000 cfs as measured at the gage at Delta

Gunnison River @ Delta Days > 15000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	0	0	0	0	0
1980	0	2	1	0	1
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	2	2	2	3	2
1984	5	8	5	5	5
1985	1	1	0	0	0
1986	0	0	0	0	0
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	1	2	1	1	1
1994	0	0	0	0	0
1995	2	3	3	3	3
1996	0	0	0	0	0
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0

Table 57 shows the number of days per year that flows in the Gunnison River as measured at the gage at Delta exceeded 14,000 cfs. Operating criteria in the Riverware model attempt to reduce releases from the Aspinall Unit once flows at Delta exceed 14,000 cfs in an effort to keep the flows from exceeding 15,000 cfs.

Table 57: Number of days per year that flows in the Gunnison River exceeded 14,000 cfs as measured at the gage at Delta

Gunnison River @ Delta Days > 14000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	0	0	0	0	0
1980	0	3	3	1	3
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	3	3	3	6	2
1984	12	13	12	12	12
1985	3	3	0	0	0
1986	0	0	0	0	0
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	2	4	3	4	3
1994	0	0	0	0	0
1995	6	5	3	7	3
1996	0	0	0	0	0
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0

Table 58 shows the number of days per year that flows in the Gunnison River as measured at the gage at Delta exceeded 12,000 cfs. Generally when the river at the Delta gage exceeds 12,000 cfs, this can initiate preparations for flooding if there is a possibility that the river flows will continue to increase.

Table 58: Number of days per year that flows in the Gunnison River exceeded 12,000 cfs as measured at the gage at Delta

Gunnison River @ Delta Days > 12000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	0	3	1	0	1
1980	2	7	9	9	9
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	7	11	9	9	8
1984	36	35	35	34	35
1985	5	5	13	21	13
1986	0	0	3	5	3
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	9	10	10	11	10
1994	0	0	0	0	0
1995	20	32	21	27	22
1996	0	0	0	1	0
1997	0	0	3	9	3
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0

Table 59 shows the number of days per year that flows in the Gunnison River as measured at the gage at Delta exceeded 10,000 cfs. It is assumed that when the Gunnison River through Delta stays below 10,000 cfs there is no immediate threat of flooding in the city.

Table 59: Number of days per year that flows in the Gunnison River exceeded 10000 cfs as measured at the gage at Delta

Gunnison River @ Delta Days > 10000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	2	2	2
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	3	6	8	14	8
1980	7	10	13	23	13
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	16	18	16	18	15
1984	53	56	54	54	54
1985	10	18	19	23	19
1986	0	3	13	16	13
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	19	26	26	25	26
1994	0	0	0	0	0
1995	47	52	53	53	53
1996	0	0	4	4	4
1997	1	3	12	22	12
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	2	1	0	0	1

Targets established in the Flow Recommendations report are all measured at the Whitewater gage on the Gunnison River. Peak flows that occurred during the month of May at the Whitewater gage for the No Action Alternative and Alternatives A, B, C and D are shown in Table 60. Annual peaks that occur during the month of May are typically products of operations at the Aspinall Unit intended to create or enhance spring peaks in the lower Gunnison River by timing releases from the Unit with the runoff peak on the North Fork of the Gunnison River.

Table 60: Annual peak flows in the Gunnison River occurring during the month of May as measured at the gage at Whitewater

Gunnison River @ Whitewater May Peak Flow (cfs)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	8924	11201	12296	12296	12296
1976	5125	9336	8386	8386	8386
1977	1199	1194	1194	1194	1194
1978	10662	10658	11364	11424	11364
1979	15161	16896	16261	16033	16261
1980	13882	16404	16326	15545	16326
1981	3771	3771	3771	3771	3771
1982	9135	9829	11023	10294	11023
1983	18051	18754	17306	17306	17306
1984	19052	19051	19053	19051	19051
1985	13735	13596	14951	15137	14999
1986	10353	11896	13231	13278	13232
1987	9713	10066	9723	10463	9723
1988	3434	3665	5814	5974	3665
1989	2462	3465	5243	5371	2462
1990	2347	2347	2347	2347	2347
1991	8409	8787	8593	8514	8580
1992	6050	6043	8583	8647	6045
1993	20489	21948	21040	21144	21058
1994	4909	4907	7755	7875	4911
1995	12899	14539	15627	15628	15625
1996	7857	9788	12412	12655	12422
1997	11993	13739	14530	14470	14531
1998	9852	10021	9158	9324	9158
1999	4139	7703	7783	8156	7783
2000	4766	4767	7840	6091	4779
2001	3491	3491	7439	6536	3491
2002	1170	1170	1170	1170	1170
2003	5310	5363	7033	7191	5310
2004	3411	3411	5207	5366	3411
2005	13572	13473	11372	11483	13516

Table 61 shows peak flows in the Gunnison River, occurring during the months of June or July, as measured at the gage at Whitewater for the No Action Alternative and Alternatives A, B, C and D. Typically, peak flows that occur during these two months are more a result of wetter hydrology that necessitates the release or spill of large volumes of water from the Aspinall Unit.

Table 61: Annual peak flows in the Gunnison River occurring during the months of June or July as measured at the gage at Whitewater

Gunnison River @ Whitewater June-July Peak Flow (cfs)					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	8010	8132	8895	8895	8895
1976	3472	3349	3768	6086	3768
1977	1573	1636	1636	1636	1636
1978	7584	7391	9667	9725	9667
1979	10485	11100	12933	14712	12933
1980	9761	9694	12219	13746	12219
1981	2611	2611	2611	2611	2611
1982	7391	6734	8199	8204	8199
1983	20481	19418	20350	19265	19058
1984	20744	20736	20941	20859	20939
1985	16498	16192	15503	15530	15504
1986	9784	9727	13727	14018	13727
1987	9199	10354	10191	9364	10191
1988	2571	2571	2571	2961	2571
1989	2363	2363	2201	4915	2363
1990	2566	2566	2566	2566	2566
1991	5999	6471	6166	6895	6151
1992	4123	4088	5974	7638	4099
1993	14515	14649	14658	14764	14656
1994	4092	4106	3451	6395	4085
1995	19506	19476	19125	18751	19130
1996	4066	5164	7510	8148	7515
1997	10625	10362	14074	14304	14075
1998	6656	6399	6631	7527	6631
1999	6857	5137	7573	7867	7337
2000	2691	2772	6185	4139	2905
2001	3380	3380	3392	2748	3380
2002	1061	1061	1061	1061	1061
2003	4942	4942	4942	4952	4942
2004	2165	2165	2165	2859	2165
2005	6296	6089	6714	6657	6778

Another goal of the Flow Recommendations other than spring peaks is to increase the number of days of high flows in the lower Gunnison River. The Flow Recommendations set targets of 8,070 cfs for median half-bankfull flow and 14,350 cfs for median bankfull flow. These two targets represent the median flows for a large number of river cross-sections from Delta downstream to Whitewater. The full range of half bankfull flows is approximately from 4,500 cfs to 12,500 cfs. The full range of bankfull flows extends from 7,500 cfs to over 28,500 cfs. Tables 62 through 71 show the number of days that flows exceed a threshold value between 5,000 cfs and 14,350 cfs for the No Action Alternative and Alternatives A, B, C and D.

Table 62: Number of days per year that flows in the Gunnison River exceed 5,000 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 5000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	41	47	39	39	39
1976	2	11	13	21	13
1977	0	0	0	0	0
1978	42	38	44	52	44
1979	67	60	75	91	75
1980	67	70	67	81	67
1981	0	0	0	0	0
1982	38	37	43	38	43
1983	89	87	91	88	91
1984	94	94	95	119	95
1985	84	84	82	82	82
1986	99	95	77	97	77
1987	60	59	59	66	59
1988	0	0	3	3	0
1989	0	0	2	7	0
1990	0	0	0	0	0
1991	26	24	24	27	24
1992	2	2	8	15	2
1993	79	73	73	78	72
1994	0	0	11	21	0
1995	94	86	88	111	87
1996	28	16	27	31	27
1997	78	76	75	81	75
1998	40	39	40	42	40
1999	12	12	17	25	16
2000	0	0	10	6	0
2001	0	0	10	6	0
2002	0	0	0	0	0
2003	2	3	9	14	2
2004	0	0	1	2	0
2005	48	43	41	37	44
Average	35.2	34.1	36.3	41.3	34.6

Table 63: Number of days per year that flows in the Gunnison River exceed 6,000 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 6000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	32	31	37	37	37
1976	0	9	11	17	11
1977	0	0	0	0	0
1978	26	23	42	50	42
1979	53	42	57	74	57
1980	61	57	55	73	55
1981	0	0	0	0	0
1982	26	23	32	29	32
1983	74	71	71	71	71
1984	86	86	87	110	86
1985	81	81	81	79	80
1986	65	65	59	79	59
1987	43	41	43	48	43
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	9	10	13	19	13
1992	1	1	5	12	1
1993	74	64	64	69	64
1994	0	0	7	17	0
1995	93	77	82	105	82
1996	10	11	23	28	23
1997	66	65	64	71	64
1998	29	28	29	33	29
1999	9	7	14	20	12
2000	0	0	7	1	0
2001	0	0	7	3	0
2002	0	0	0	0	0
2003	0	0	3	7	0
2004	0	0	0	0	0
2005	31	26	26	24	29
Average	28.0	26.4	29.6	34.7	28.7

Table 64: Number of days per year that flows in the Gunnison River exceed 7,000 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 7000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	26	16	33	33	33
1976	0	7	8	10	8
1977	0	0	0	0	0
1978	14	13	36	45	36
1979	35	29	44	56	44
1980	50	46	45	65	45
1981	0	0	0	0	0
1982	16	15	23	26	23
1983	59	58	67	66	66
1984	78	75	77	103	79
1985	75	72	73	72	73
1986	41	39	44	65	44
1987	32	32	34	36	34
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	4	4	9	9	9
1992	0	0	3	7	0
1993	66	58	58	63	56
1994	0	0	4	13	0
1995	76	74	74	102	74
1996	7	9	20	26	20
1997	56	53	50	63	50
1998	17	17	14	20	14
1999	0	4	11	17	8
2000	0	0	3	0	0
2001	0	0	3	0	0
2002	0	0	0	0	0
2003	0	0	1	1	0
2004	0	0	0	0	0
2005	19	18	17	15	19
Average	21.6	20.6	24.2	29.5	23.7

Table 65: Number of days per year that flows in the Gunnison River exceed 8,070 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 8070 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	7	9	23	23	23
1976	0	2	2	2	2
1977	0	0	0	0	0
1978	10	6	22	25	22
1979	26	27	33	39	33
1980	41	36	36	40	36
1981	0	0	0	0	0
1982	8	12	14	10	14
1983	53	53	54	54	59
1984	67	67	67	79	67
1985	59	57	56	54	56
1986	23	22	27	38	27
1987	15	15	16	18	16
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	1	2	1	1	1
1992	0	0	1	1	0
1993	49	48	49	49	48
1994	0	0	0	0	0
1995	72	73	72	79	72
1996	0	6	9	10	9
1997	48	46	37	42	37
1998	5	8	5	7	5
1999	0	0	0	1	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	12	12	8	8	12
Average	16.0	16.2	17.2	18.7	17.4

Table 66: Number of days per year that flows in the Gunnison River exceed 9,000 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 9000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	6	7	7	7
1976	0	2	0	0	0
1977	0	0	0	0	0
1978	3	3	13	13	13
1979	18	18	24	31	24
1980	26	24	29	32	29
1981	0	0	0	0	0
1982	1	5	7	4	7
1983	51	51	51	51	53
1984	59	59	59	59	59
1985	42	41	39	43	39
1986	14	14	21	28	21
1987	5	7	6	5	6
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	35	40	41	42	41
1994	0	0	0	0	0
1995	67	69	70	69	70
1996	0	4	6	6	6
1997	29	30	21	28	21
1998	1	4	1	1	1
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	9	9	7	6	9
Average	11.6	12.5	13.0	13.7	13.1

Table 67: Number of days per year that flows in the Gunnison River exceed 10,000 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 10000 cfs	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	4	6	6	6
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	2	2	9	9	9
1979	16	16	22	30	22
1980	13	12	17	26	17
1981	0	0	0	0	0
1982	0	0	6	2	6
1983	43	43	44	44	44
1984	56	58	56	57	56
1985	30	30	31	35	31
1986	4	7	17	24	17
1987	0	2	1	2	1
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	24	35	35	34	35
1994	0	0	0	0	0
1995	61	64	69	68	69
1996	0	0	4	5	4
1997	11	11	15	25	15
1998	0	1	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	7	7	5	5	7
Average	8.6	9.4	10.9	12.0	10.9

Table 68: Number of days per year that flows in the Gunnison River exceed 11,000 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 11000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	1	4	4	4
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	2	2	2
1979	12	13	21	27	21
1980	7	7	13	24	13
1981	0	0	0	0	0
1982	0	0	1	0	1
1983	33	31	36	38	32
1984	53	56	53	53	53
1985	21	24	27	31	27
1986	0	4	13	17	13
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	22	28	28	27	28
1994	0	0	0	0	0
1995	55	59	65	65	65
1996	0	0	4	3	3
1997	3	5	13	24	13
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	6	6	2	2	6
Average	6.8	7.5	9.1	10.2	9.1

Table 69: Number of days per year that flows in the Gunnison River exceed 12,000 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 12000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	2	2	2
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	8	9	11	17	11
1980	3	6	10	18	10
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	28	27	26	31	27
1984	48	47	49	47	49
1985	15	18	22	28	22
1986	0	0	9	11	9
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	21	24	25	26	25
1994	0	0	0	0	0
1995	47	54	56	55	56
1996	0	0	1	1	1
1997	0	3	9	19	9
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	5	4	0	0	4
Average	5.6	6.2	7.1	8.2	7.3

Table 70: Number of days per year that flows in the Gunnison River exceed 13,000 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 13000 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	5	6	6	11	6
1980	2	4	4	7	4
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	22	23	21	23	21
1984	39	37	38	40	38
1985	7	11	12	18	13
1986	0	0	6	7	6
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	19	21	22	22	22
1994	0	0	0	0	0
1995	38	48	41	41	42
1996	0	0	0	0	0
1997	0	1	5	10	5
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	3	2	0	0	2
Average	4.4	4.9	5.0	5.8	5.1

Table 71: Number of days per year that flows in the Gunnison River exceed 14,350 cfs as measured at the gage at Whitewater

Gunnison River @ Whitewater Days > 14350 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	0	0	0	0
1978	0	0	0	0	0
1979	4	6	4	5	4
1980	0	3	3	2	3
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	13	17	16	16	16
1984	28	26	25	25	25
1985	3	3	5	5	5
1986	0	0	0	0	0
1987	0	0	0	0	0
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	17	17	17	17	17
1994	0	0	0	0	0
1995	21	31	22	26	21
1996	0	0	0	0	0
1997	0	0	1	1	1
1998	0	0	0	0	0
1999	0	0	0	0	0
2000	0	0	0	0	0
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0
Average	2.8	3.3	3.0	3.1	3.0

The Redlands Power Canal diverts water from the Gunnison River downstream of the gage at Whitewater. The power canal has water rights senior to the Aspinall Unit that total 750 cfs. The significance of the Redlands Canal not being able to divert 750 cfs is that this could initiate a call from the Redlands Power Company that could affect upstream users with priority dates later than 1941.

Table 72 shows the number of days per year that the Redlands Power Canal diverts less than 750 cfs for the No Action Alternative and Alternatives A, B, C and D. This does not automatically mean a call on the river is in place but it does create the potential for a call by the Redlands Power Company.

Table 72: Days per year that the Redlands Power Canal diverts less than 750 cfs.

Redlands Canal Days < 750 cfs					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	33	18	18	18	18
1976	8	11	11	11	11
1977	218	179	179	179	179
1978	70	35	37	38	37
1979	0	0	0	0	0
1980	6	2	3	10	3
1981	68	35	38	39	38
1982	0	0	0	11	0
1983	0	0	0	0	0
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	0	0	0
1987	0	0	0	0	0
1988	4	3	3	4	3
1989	0	0	2	5	0
1990	66	42	42	43	42
1991	0	1	9	31	1
1992	0	0	0	0	0
1993	0	0	0	0	0
1994	0	0	0	0	0
1995	0	0	0	0	0
1996	0	0	0	0	0
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	3	2	3	2	3
2000	0	0	3	1	0
2001	0	0	7	0	0
2002	114	60	68	67	60
2003	153	56	56	56	56
2004	49	30	31	31	30
2005	0	0	0	0	0
Average	25.5	15.3	16.5	17.6	15.5

Downstream of the Redlands Power Canal Diversion Dam lies the final miles of the Gunnison River before it joins the Colorado River in Grand Junction. During wetter periods there is usually sufficient water downstream of the diversion dam. However, this stretch of river can experience very low flows due to the diversion of the majority of water by the power canal during drier periods. Endangered fish need sufficient flows to migrate up the Gunnison River. Most of this migration occurs from April through September. When flows drop below 100 cfs downstream of the diversion dam fish migration may become impossible. Table 73 shows the number of days from April through September that flows in the Gunnison River downstream of the Redlands diversion dam fall below 100 cfs for the No Action Alternative and Alternatives A, B, C and D. As can be seen in the table this condition occurs primarily during drought years.

Table 73: Days per year that flows below the Redlands Diversion Dam are less than 100 cfs during the months of April through September

Gunnison River below Redlands Canal Days < 100 cfs Apr-Sep					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0	0
1976	0	0	2	3	2
1977	18	27	27	27	27
1978	0	0	0	3	0
1979	0	0	0	1	0
1980	3	3	3	10	3
1981	20	23	24	27	24
1982	0	0	0	0	0
1983	0	0	0	0	0
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	0	0	0
1987	0	0	0	0	0
1988	6	3	4	6	3
1989	5	0	1	5	0
1990	19	11	12	11	13
1991	0	0	0	0	0
1992	0	0	0	0	0
1993	0	0	0	0	0
1994	0	0	0	5	0
1995	0	0	0	0	0
1996	0	0	0	0	0
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	5	5	5	5	5
2000	2	1	4	1	1
2001	0	0	0	0	0
2002	17	28	28	28	28
2003	9	16	16	16	16
2004	11	6	9	9	6
2005	0	0	0	0	0
Average	3.7	4.0	4.4	5.1	4.1

A fish ladder is currently in place at the Redlands Diversion Dam which enables the endangered fish to navigate around this structure. The ladder is most effective when flows in the Gunnison River downstream of the diversion dam are above 300 cfs. Most endangered fish travel upstream from April through September. Table 74 shows the number of days from April through September that flows in the Gunnison River downstream of the Redlands Diversion Dam drop below 300 cfs for the No Action Alternative and Alternatives A, B, C and D. Again, the impacts to fish migration generally occur during drought years.

Table 74: Days per year that flows below the Redlands Diversion Dam are less than 300 cfs during the months of April through September

Gunnison River below Redlands Canal Days < 300 cfs Apr-Sep					
	NoAction	Alt A	Alt B	Alt C	Alt D
1975	0	0	0	0	0
1976	31	36	42	66	42
1977	179	179	179	179	179
1978	7	9	47	43	47
1979	0	0	10	18	10
1980	15	8	9	26	9
1981	104	105	106	106	106
1982	0	0	0	8	0
1983	0	0	0	0	0
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	0	0	0
1987	0	0	0	0	0
1988	40	37	47	58	37
1989	38	40	46	79	39
1990	83	85	96	104	83
1991	0	1	1	2	0
1992	0	0	0	3	0
1993	0	0	0	0	0
1994	18	17	21	23	18
1995	0	0	0	0	0
1996	0	0	3	11	3
1997	0	0	0	0	0
1998	0	0	0	0	0
1999	15	15	15	15	15
2000	21	20	31	28	19
2001	5	5	17	6	5
2002	157	157	164	159	157
2003	105	89	89	89	89
2004	63	74	75	75	76
2005	1	1	1	4	1
Average	28.5	28.3	32.2	35.5	30.2

Appendix B

Biological Assessment

RECLAMATION

Managing Water in the West

PROGRAMMATIC BIOLOGICAL ASSESSMENT: GUNNISON RIVER BASIN, COLORADO: OPERATIONS OF THE WAYNE N. ASPINALL UNIT; OPERATIONS AND DEPLETIONS OF EXISTING RECLAMATION PROJECTS; AND OPERATIONS AND DEPLETIONS OF NON-FEDERAL WATER DEVELOPMENT

December 23, 2008

United States Department of Interior
Bureau of Reclamation
Upper Colorado Region
Western Colorado Area Office

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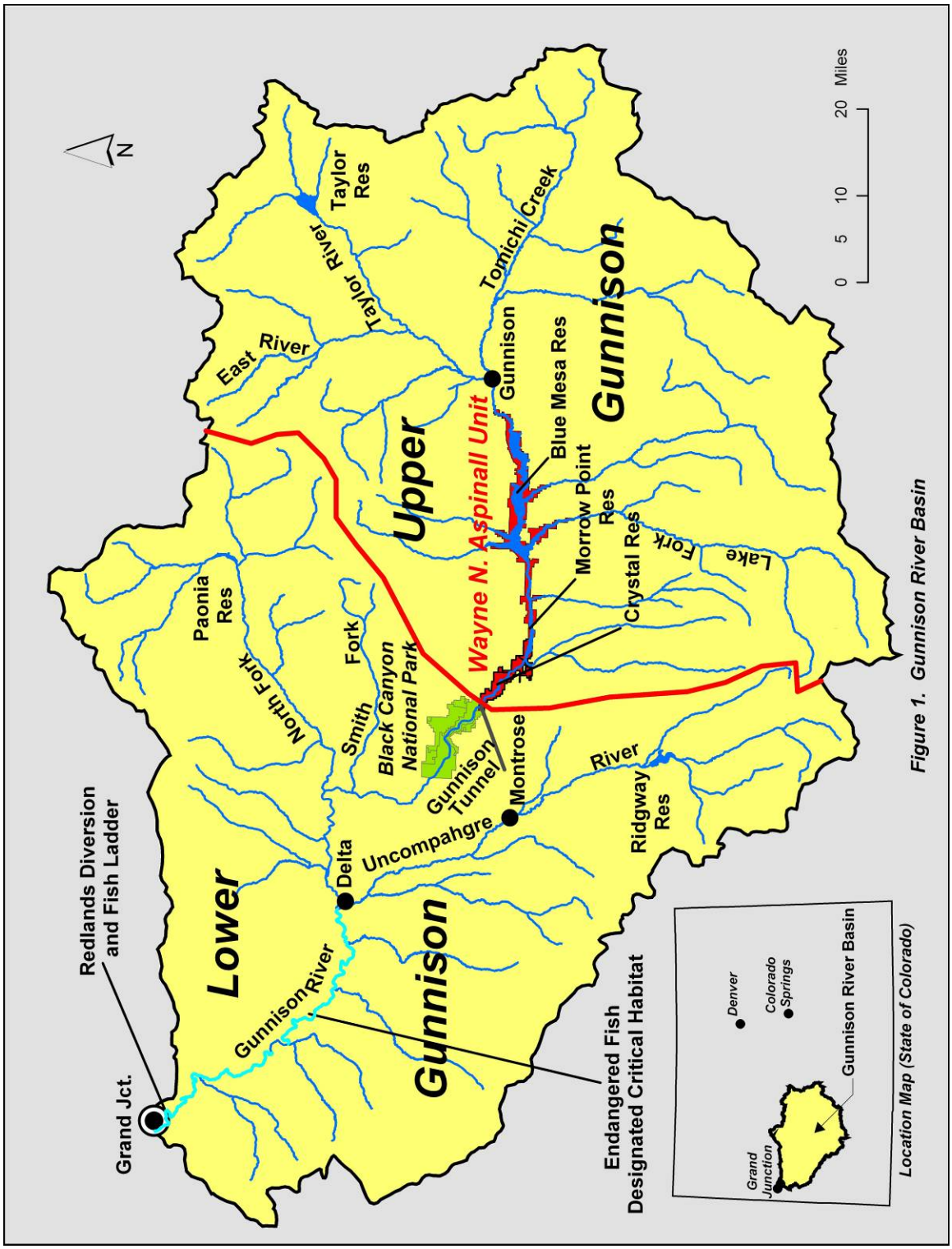
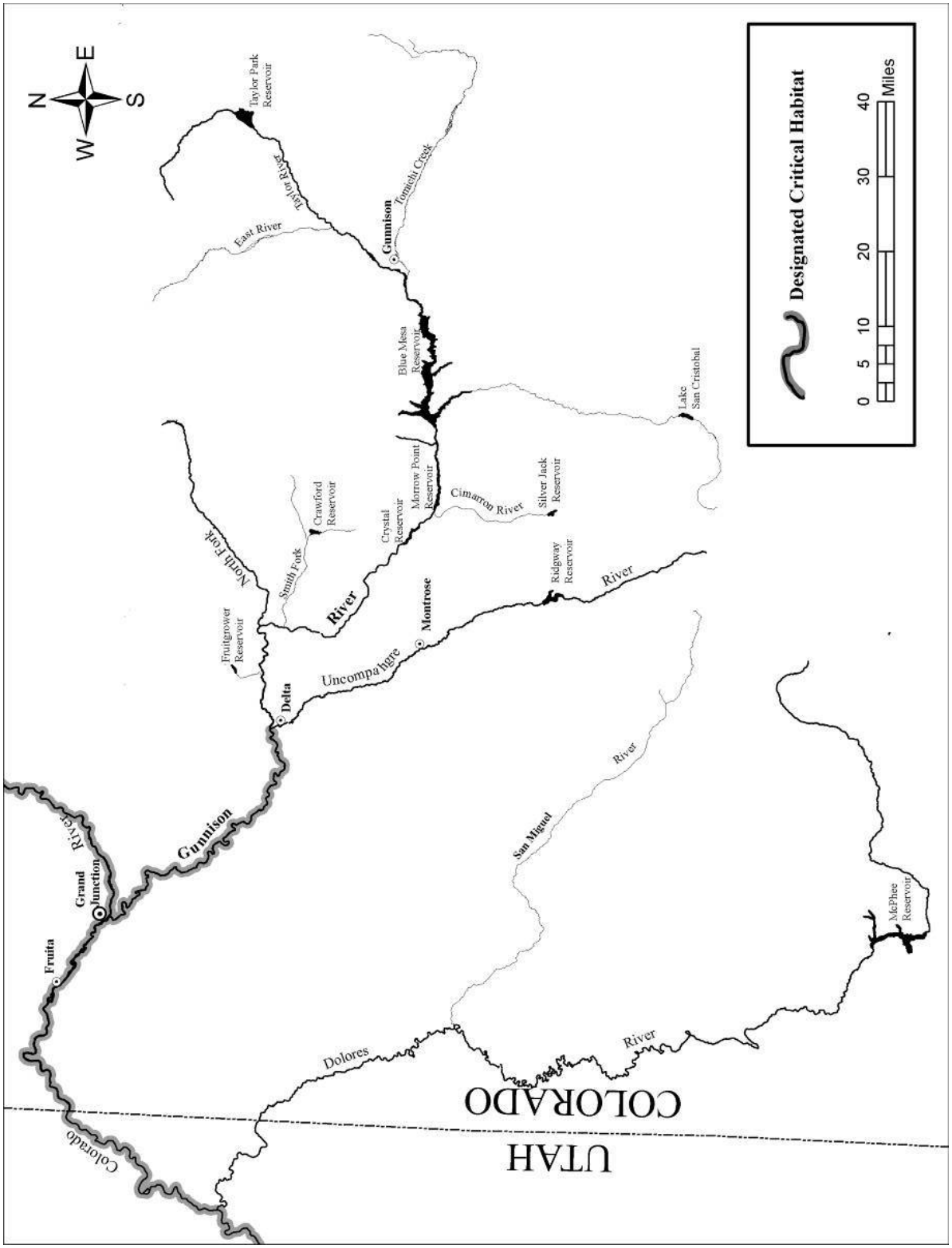


Figure 1. Gunnison River Basin


N
E
S
W
Designated Critical Habitat
0 5 10 20 30 40
Miles
Taylor Park Reservoir
Taylor River
East River
Gunnison
Tomichi Creek
Blue Mesa Reservoir
Lake San Cristobal
Morrow Point Reservoir
Crystal Reservoir
Cimarron River
Silver Jack Reservoir
Crawford Reservoir
Smith Fork
North Fork
Ridgway Reservoir
River
Montrose
Fruitgrower Reservoir
Uncompahgre
Delta
River
Gunnison
Grand Junction
Fruita
San Miguel
River
McPhee Reservoir
Dolores
River
COLORADO
UTAH
Colorado

PROGRAMMATIC BIOLOGICAL ASSESSMENT: GUNNISON RIVER BASIN, COLORADO: OPERATIONS OF THE WAYNE N. ASPINALL UNIT; OPERATIONS AND DEPLETIONS OF EXISTING RECLAMATION PROJECTS; AND OPERATIONS AND DEPLETIONS OF NON-FEDERAL WATER DEVELOPMENT

1.0 INTRODUCTION

1.1 General

The Bureau of Reclamation (Reclamation), in cooperation with interested non-federal parties, is submitting this programmatic biological assessment (PBA) to the Fish and Wildlife Service (Service) in compliance with Section 7(a)(2) of the Endangered Species Act (ESA), 16 U.S. Code 1536(a)(2). This PBA addresses the potential effects of Reclamation's discretionary actions related to water management operations throughout the Gunnison Basin, and Dolores Project operations in the Dolores River/Colorado River basins in west central Colorado and eastern Utah.

The purpose of this PBA is to evaluate the impacts of Reclamation's proposed action, which includes reoperation of the Wayne N. Aspinall Unit (Aspinall Unit), on threatened, endangered, and candidate species and on critical habitat. Preparation of the PBA has been coordinated with the state and private agencies/organizations in the action area. Foreseeable future changes to the environment that result from continuation of state and private water related actions are included in the PBA effects analysis.

The Service has cited 9 endangered, 4 threatened, and 2 candidate species potentially affected by the proposed action based on their presence in the Gunnison or portions of the Colorado River Basin (Fish and Wildlife Service 2008):

Clay-loving wild buckwheat	*Eriogonum pelinophilum*	endangered
Uinta Basin hookless cactus	*Sclerocactus glaucus*	threatened
Jones' cycladenia	*Cycladenia humilis var. jonesii*	threatened
Yellow-billed cuckoo	*Coccyzus americanus*	candidate
Mexican spotted owl	*Strix occidentalis lucida*	threatened
Southwestern willow flycatcher	*Empidonax traillii extimus*	endangered
California condor	*Gymnogyps californianus*	endangered
Colorado pikeminnow	*Ptychocheilus lucius*	endangered
Razorback sucker	*Xyrauchen texanus*	endangered
Humpback chub	*Gila lacypha*	endangered
Bonytail	*Gila elegans*	endangered
Black-footed ferret	*Mustela nigripes*	endangered
Canada lynx	*Lynx Canadensis*	threatened
Gunnison's prairie dog	*Cynomys gunnisoni*	candidate
Uncompahgre fritillary butterfly	*Boloria acrocnema*	endangered

The timeframe addressed in the assessment is considered to be 25 years from completion of the biological opinion. The action area for this assessment is the Gunnison River Basin and the Upper Colorado River downstream from the Gunnison confluence to the

Dolores River confluence and downstream to Lake Powell. The Aspinall Unit itself is located in Gunnison and Montrose Counties, Colorado, along a 40-mile reach of the Gunnison River as shown on the frontispiece maps. Downstream from the Aspinall Unit, the Gunnison River also flows through Delta and Mesa Counties. The Aspinall Unit consists of a series of three dams and reservoirs: Blue Mesa, Morrow Point, and Crystal. The Aspinall Unit was authorized by the Colorado River Storage Project Act of 1956 (CRSPA) along with Glen Canyon, Flaming Gorge, and the Navajo Unit. All are operated by the Reclamation. The authorization calls for meeting a variety of purposes listed in Section 2.7.

1.2 Summary of the Proposed Action

1.2.1 Federal Action

"Action" is defined as all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies. The Service's regulations at 50 CFR 402.03 provide that Section 7 applies to all actions in which there is discretionary Federal involvement or control.

The proposed Federal action analyzed in this PBA includes those discretionary actions proposed by Reclamation regarding water operations and management in the Gunnison Basin and in the portion of the Colorado River affected by the Dolores Project and Aspinall Unit. The elements of the Federal action are:

- Reclamation's modification of the operation of the Aspinall Unit to avoid jeopardy to downstream endangered fish in the Gunnison and Colorado rivers. The new operation is designed to increase downstream spring peak flows while maintaining moderate base flows. A detailed description is found in Section 2.1.2.
- The continuation of all of Reclamation Project operations in the Gunnison River Basin. Reclamation projects are: Smith Fork, Paonia, Fruitgrowers, Bostwick Park, and Uncompahgre (Attachment 1).
- The continued operation of the Dolores Project (Attachment 1) in the Dolores Basin, included based on a prior biological opinion Reasonable and Prudent Alternative, and reinitiation of consultation on it to address new listed species and depletions.
- The continued operation of the Dallas Creek Project (Attachment 1) included based on a prior biological opinion Reasonable and Prudent Alternative, and reinitiation of consultation on it to address new listed species and depletions.
- Actions undertaken by the Service, Reclamation, the National Park Service, and Western Area Power Administration in the funding and carrying out of recovery actions for the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin (Recovery Program) that affect the Gunnison Basin. See Section 2.8.

- The continued operation and use of water rights of Federal agencies such as the Bureau of Land Management, Forest Service, and National Park Service. These are generally small stock watering facilities or wells and springs.

1.2.2 Non-Federal Action

In addition to Reclamation actions, there are state organizations and private entities in the action area included in this consultation.

- The continuation of the operations and depletions of all non-Federal projects and water uses in the Gunnison Basin. Average annual depletions from these uses are estimated at approximately 250,000-275,000 acre-feet (af).
- The future depletion 3,500 af of unspecified depletions in the Gunnison Basin is also included in the action as well as 30,800 af of Aspinall Unit water rights subordinated to upstream uses.

1.3 General Description of Action Area

The Gunnison River originates where the East and Taylor Rivers join at Almont, Colorado, in Gunnison County, Colorado (Frontispiece). From that point, the river flows 25 miles to Blue Mesa Reservoir and on through Morrow Point and Crystal Reservoirs. From Crystal Reservoir, it flows approximately two miles to the Gunnison Tunnel. From the Gunnison Tunnel, the river flows for 29 miles to the confluence with the North Fork of the Gunnison (North Fork). It then travels 75 miles to its confluence with the Colorado River at Grand Junction, Colorado. The lower river has been divided into river miles (RM) for research purposes. Key river miles are listed below:

- RM 0 Colorado River confluence
- RM 3 Redlands Diversion
- RM 12 Craig Bottomland pond
- RM 14 Whitewater gage
- RM 18 Kannah Creek confluence
- RM 23 Deer Run
- RM 29 Deer Creek confluence (Bridgeport)
- RM 30 Dominquez Creek
- RM 35 Peeples Orchard
- RM 38 Wells Gulch
- RM 42 Escalante Creek
- RM 50 Roubideau Creek
- RM 53 Escalante State Wildlife Area backwaters
- RM 56 Uncompahgre River confluence
- RM 60 Hartland Diversion
- RM 65 Austin
- RM 75 North Fork confluence
- RM 104 Gunnison Tunnel
- RM 106 Crystal Dam

The area of the watershed upstream from the Aspinall Unit is approximately 4,000 square miles. At the U.S. Geological Survey gage downstream from the Gunnison Tunnel and Crystal Dam, historical average annual flows have been 1,320 cubic feet per second (cfs) and mean daily flow extremes pre-Aspinall Unit ranged from a few days of no flows to 19,000 cfs. Another important measurement point on the river is the U.S.G.S.

Whitewater gage (Gunnison River near Grand Junction), 14 miles upstream from the Colorado River confluence. At this point the drainage area is roughly 8,000 square miles, average monthly flows are approximately 2,600 cfs, and pre-Aspinall Unit extremes ranged from 106 cfs to over 35,000 cfs.

The upper portion of the Gunnison River Basin is characterized by mountainous landscape with perennial mountain streams that peak during spring snow melt. The basin area is moderately wet to semi-arid; the major part of this area being greater than 6,000 feet in elevation. Major tributaries include the East and Taylor Rivers, Tomichi Creek, the Lake Fork, and Cimarron Creek. Vegetation ranges from mixed conifer and aspen in the mountain areas to sagebrush communities in the valleys. Predominant riparian vegetation consists of narrowleaf cottonwood, box elder, willows, spruce, and other conifers. The town of Gunnison is the major community in the upper basin.

The lower (western) portion of the Gunnison River Basin is characterized by desert landscape with two major tributaries-the North Fork and the Uncompahgre River. There are also small perennial tributaries and intermittent washes that carry significant sediment loads during periodic thunderstorms. The area is semiarid to arid; the major part of this area is less than 6,000 feet in elevation and receives less than 8 inches of precipitation annually. Vegetation ranges from pinon-juniper on mesa tops to desert shrubs and grasses near the lower Gunnison and Colorado rivers. The river supports riparian vegetation such as cottonwood, willow, and non-native salt cedar and Russian olive. The Black Canyon of the Gunnison National Park and the Gunnison Gorge National Conservation Area are downstream from Crystal Dam. The cities of Delta and Grand Junction are located along the lower Gunnison River.

The Colorado River downstream from the Gunnison River confluence flows through the Grand Valley and then enters Utah and eventually Lake Powell. Lands along the Colorado River are semi-arid with numerous canyon reaches.

There are no significant water imports to or exports from the Gunnison Basin. Approximately 1,600 af are imported and 3,500 af are exported. This excludes consideration of the two diversions near the mouth of the river, the Redlands Diversion (approximately 510,000 af) and the Grand Junction water system (approximately 7,000 af).

There are approximately 264,000 irrigated acres in the basin and irrigation represents the major water use (Colorado Department of Natural Resources 2006). Major private and federal storage reservoirs in the basin are tabulated in Table 1.

Average annual depletions above the Whitewater gage are approximately 450,000-500,000 af. Approximately 45% of the depletions are related to Federal projects and 55% to private projects.

Table 1. Major water storage reservoirs, Gunnison Basin.

Reservoir	Total storage capacity (acre-feet)
Blue Mesa Reservoir	940,700
Morrow Point Reservoir	117,190
Taylor Park Reservoir	106,700
Ridgway Reservoir	94,176
Crystal Reservoir	25,240
Paonia Reservoir	20,950 (15,977 present capacity)
Crawford Reservoir	14,395
Silver Jack Reservoir	13,520
Gould Reservoir	9,000
Overland Reservoir	5,828
Fruitgrowers Reservoir	4,540 (3,576 present capacity)

Annual evaporation depletions at the Aspinall Unit averaged 8,100 acre-feet in the 2001-2005 period and 8,700 af in the 1975-1995 period. Depletions from water sales from the Aspinall Unit are less than 1,000 af annually.

2.0 DESCRIPTION OF PROPOSED ACTION

2.1 Aspinall Unit Operations

This section describes the process that Reclamation will use to implement the proposed modification of Aspinall Unit operations while maintaining other authorized purposes and assuring safe operations. The modification of the operations of the Aspinall Unit portion of the proposed action will be implemented by Reclamation following signature of a Record of Decision prepared under the National Environmental Policy Act.

RiverWare was the simulation software selected by Reclamation for use in the development of a hydrology model to be used to evaluate and compare alternatives. The Gunnison River model simulates historic hydrology from 1975 to 2005. This period of record was selected as the most complete historical dataset at the time that model analysis began. The initial conditions of the Gunnison River model were selected to be the state of the Aspinall Unit and Gunnison River system at the start of January of 1975. The Gunnison River model runs for the 31 year period between 1975 and 2005. The model runs a single trace of 31 years during this time period. The model separates annual reservoir operations into 3 time periods: January-March, April-July, and August-December. Basic daily input data to the model are: historic Blue Mesa inflows, both actual and unregulated; historic side inflows to Morrow Point and Crystal; Gunnison Tunnel diversions; and various downstream gains computed from actual gage data. Other data provided as input to the model include forecasted inflow and Gunnison Tunnel demands for each forecast period.

The model will not be used for actual operations. Operations of the Aspinall Unit will be based upon forecasted inflow volume to Blue Mesa Reservoir as well as other factors such as storage levels, physical capabilities of the facilities, and flood control to determine the magnitude, duration, and timing of releases. The spring inflow is highly

variable and dependent on the previous winter's snowpack. For example, between 1975 and 2005 the April-July Blue Mesa inflow ranged between 166,700 af in 1977 and 1,434,000 af in 1984. Because of this, the operating plan will vary from year to year based on the forecasted inflow to Blue Mesa Reservoir.

In terms of downstream endangered fish, the new operation plan has four basic goals:

- Attempting to meet spring peak targets as outlined in the Flow Recommendations;
- Attempting to meet minimum duration targets for half bankfull discharge and bankfull discharges pursuant to the Flow Recommendations;
- Attempting to meet targets for base flows as outlined in the Flow Recommendations; and
- Attempting to meet fish ladder, fish screen, and migration flows at and below the Redlands Water and Power Diversion Dam (Redlands Diversion).

2.1.1 Flow Recommendations

Flow Recommendations (McAda 2003) can be found at Http://www.usbr.gov/uc/wcao/rm/aspeis/pdfs/GunnCoFlowRec.pdf.

Flow Recommendations for the Gunnison and mainstem Colorado rivers were published by the Recovery Program (McAda 2003) and recommend flows designed to create and maintain habitat conditions that the four endangered fish species require for all aspects of their life history. Flow Recommendations were developed during conditions including the existence and operation of the Aspinall Unit. In general, the recommendations concentrate on a more natural hydrograph with high spring peak flows and moderate base flows; the flow recommendations vary from year to year based on snowpack and forecasted spring runoff. The flow "targets" in the recommendations are measured at the U.S.G.S. gaging station at Whitewater on the Lower Gunnison River. In addition, recommendations for the Colorado River are targeted at the U.S.G.S. Colorado-Utah stateline gaging station. Flow Recommendations are summarized in Attachment 2.

While habitat needs of the endangered fish vary between species, spring peak flows benefit all the species by accomplishing several physical goals in addition to providing cues for migration and spawning:

- Maintain complex in-channel habitats
- Provide access to floodplains
- Minimize vegetation encroachment, channel narrowing, and vertical accretion, thus protecting side-channel habitats
- Form low-velocity habitats for staging, feeding, and resting during runoff
- Inundate and maintain connections to floodplains and off-channel habitat to provide warmer water food-rich conditions for larval and adult fish
- Provide clean spawning substrates and adequate interstitial spaces for periphyton and aquatic invertebrates

Overall, the priority in the Flow Recommendations is peak flows in the spring. Also included are relatively high base flows in wet years and relatively lower base flows in drier years. Flow Recommendation targets are based on meeting half bankfull and bankfull discharges to reach or exceed thresholds for sediment movement with higher instantaneous peaks in some years.

Pitlick et al. (1999) summarized the importance of spring flows in moving sediment:

> The single most important thing that can be done to maintain habitats used by the endangered fishes is to assure that the sediment supplied to the critical reaches continues to be carried downstream. Sediment that is not carried through will accumulate preferentially in low velocity areas, resulting in further channel simplification and narrowing.

Pitlick et al. (1999) also provided specific flow targets based on Gunnison River field studies:

> Flows equal to or greater than one-half the bankfull discharge are needed to mobilize gravel and cobble particles on a widespread basis and to prevent fine sediment from accumulating in the bed…Flows greater than one-half the bankfull discharge thus provide several important geomorphic functions, assuming they occur with sufficient regularity. Flows equal to bankfull discharge are also important because they fully mobilize the bed and thereby maintain the existing bankfull hydraulic geometry.

As discussed in Section 3.2, the median value for half bankfull flows is 8,070 cfs and the half bankfull flow range is 4,660 to 12,700 cfs as determined from 54 different cross sections along the Gunnison River in critical habitat. The median value for bankfull flows is 14,350 cfs with a range of 7,352 to 28,000 cfs. Corresponding median values for the Colorado River at the Colorado-Utah stateline are 18,500 cfs and 35,000 cfs.

Fish and Wildlife Service (2004) referred to several studies in the Upper Colorado Basin that indicated a relationship of strong year classes of pikeminnow with hydrologic conditions that included a spring and summer of moderately high flows following a year of exceptionally high flows.

Bottomland or floodplain habitats provide important habitat to several life stages of endangered fish. Irving and Burdick (1995) studied bottomlands on the Gunnison River. In 1993, 48 bottomland sites were identified on the Gunnison River with a total potential area of 3,227 acres. Of this total, approximately 828 acres were inundated at spring flows (of approximately 14,000 cfs) and 161 acres at lower fall flows (approximately 2,400 cfs). Limited inundation of floodplains began around 5,000 - 6,000 cfs; however, significant acreage inundation did not occur until flows reached 10,000-15,000 cfs. Bottomlands included terraces, depressions, gravel pits, oxbows, side channels, and canyon mouths.

The majority of the floodplain habitat within critical habitat in the Gunnison River is located between Delta and the confluence with Roubideau Creek-- Johnson Boys' slough, Escalante State Wildlife Area (SWA), Confluence Park, Morgan, and Fedler (Valdez and Nelson 2006). The greatest potential for flooded habitat occurs at the Escalante SWA (RM 50-52) where the greatest relative gain in flooded habitat occurs as flows increase to 10,000 cfs. McAda and Fenton (1998) evaluated available habitat in Escalante SWA in relation to flow and determined that little relative gain occurs between 981 and 5,560 cfs, but substantial increases occur between 5,560 and 13,300 cfs and diminish again at higher levels. The Johnson Boy's slough (RM 52-54) is another important site. Further downstream, the river enters a valley in the Whitewater area where railroad construction and other developments have restrained the river in the main channel since the late 19th century. A few sites are located close to the Colorado River confluence-for example the Craig site that has been acquired and improved by the Recovery Program. Water begins to enter the Craig site as flows reach 4,500 to 5,000 cfs.

Among Gunnison River floodplain habitats, the Recovery Program prioritized the Johnson Boy's slough and Escalante SWA as #2 and #8 among 26 potential sites in the entire Upper Colorado River basin (Valdez and Nelson 2006). Prioritizations were based on location, size, connectivity and land ownership. In the Colorado River below the Gunnison River confluence, nineteen sites were identified. Of these, Walter Walker SWA was ranked #1 in the entire Upper Colorado River basin, and the Panorama site was ranked #6 overall.

To incorporate natural variation in the river system, flow recommendations were developed for six hydrological categories based on April-July runoff volumes. An indication of the variability of water availability in the Gunnison River is the range of April-July runoff volume at Whitewater – 281,000 af in 1977 and 3,147,000 af in 1984. The six hydrological categories are:

- Wet years: April-July runoff volume has been equaled or exceeded 10% of the time during the study period.
- Moderately wet years: April-July runoff volume has been equaled or exceeded 10-30% of the time during the study period.
- Average wet years: April-July runoff volume has been equaled or exceeded 30-50% of the time during the study period.
- Average dry years: April-July runoff volume has been equaled or exceeded 50-70% of the time during the study period.
- Moderately dry years: April-July runoff volume has been equaled or exceeded 70-90% of the time during the study period.
- Dry years: April-July runoff volume has been equaled or exceeded 90% of the time during the study period.

Water inflow to Blue Mesa Reservoir for the six categories was estimated by McAda (2003) based on 1937-1997 data:

- Wet years: inflow of 1,123,000 af or greater

- Moderately wet years: inflow between 871,000 af and 1,123,000 af
- Average wet years: inflow between 709,000 af and 871,000 af
- Average dry years: inflow between 561,000 af and 709,000 af
- Moderately dry years: inflow between 381,000 af and 561,000 af
- Dry years: inflow less than 381,000 af

The Flow Recommendations adopted Pitlick's analysis that to maintain habitat conditions in the Gunnison and Colorado rivers, half bankfull and bankfull flows should occur with a long-term average duration equal to what occurred during 1978-1997 and that to improve habitat, the threshold flows should occur with a long-term average equal to what occurred during 1993-1997. "Pitlick et al.'s (1999) recommendation to maintain habitat conditions would mean that over the long term flows should exceed 8,070 cfs for an average of 20 days per year and flows should exceed 14,350 cfs for an average of 4 days per year. Their recommendation to improve habitat conditions requires that, over the long term, flows should exceed 8,070 cfs for an average of 32 days per year and flows should exceed 14,350 cfs for an average of 7 days per year" (McAda, 2003). While target durations are based on geomorphology studies, durations of higher flows are also important for maintaining use of floodplain and backwater habitats.

Table 2 presents one of the possible scenarios by which flow recommendations for the Gunnison River could be derived from Pitlick's work (McAda 2003).

Table 2. Peak flow recommendations for the Gunnison River-number of days per years the flows should exceed half bankfull and bankfull.

Hydrologic Category	Expected Occurrence	Flow Target and Duration		Instantaneous Peak Flows cfs
		Days/Year Greater or equal To 8,070 cfs*	Days/Year Greater or equal to 14,350 cfs*	
Wet	10%	60-100	15-25	15-23,000
Moderately Wet	20%	40-60	10-20	14,350-16,000
Average Wet	20%	20-25	2-3	=/> 14,350
Average Dry	20%	10-15	0-0	=/> 8,070
Moderately Dry	20%	0-10	0-0	=/> 2,600
Dry	10%	0-0	0-0	~ 900-4,000
Long Term Weighted Average		20-maintenance 32-improvement	4-maintenance 7-improvement	

*Lower value in each range is for maintenance, higher value in each range is for improvement

Peak flows in the Gunnison River are recommended to occur between May 15 and June 15 and should be managed, to the extent possible, by matching peak flows in the North Fork of the Gunnison with peak releases from the Aspinall Unit.

Peak flow recommendations were developed in a similar manner for the Colorado River measured at the Colorado-Utah stateline (see Attachment 2 and McAda 2003).

A minimum base flow for the Gunnison River (as measured at Whitewater gage) of at least 1,050 cfs is recommended in all but moderately dry and dry years in order to protect quiet water habitats for the fish and provide migration flows below the Redlands Fish Ladder. Included would be flows of 100 cfs to operate the fish ladder. It has been recommended that the ladder be operated from April 1 through September 15 (Burdick 2001). During dry and moderately dry years, flow recommendations provide for flows decreasing below 1,050 cfs after the Colorado pikeminnow migration period. During wetter periods, base flow recommendations are higher.

The Flow Recommendations recognize uncertainties (Section 6.7) in understanding the biology of the fishes and the response of the fish and their habitat to flow changes. For that reason, the recommendations call for using adaptive management to respond to new knowledge and using monitoring to evaluate the physical response of the habitat and biological response of the fish to the flow regimes.

In summary, the Flow Recommendations call for peak flows to periodically prepare cobble and gravel spawning areas, to connect backwaters, and to maintain channel diversity; and sufficient flows to cue and allow migration. Base flows that promote growth and survival of young fish during summer, autumn, and winter are also provided.

2.2.2 Planned Operations

The plan modifies operations where Reclamation has discretion to do so. There are elements of existing operations that are non-discretionary and are not changed. These non-discretionary operations are based on legal authorities, existing water rights, structural limitations, structural safety consideration, flood control rules, and existing water service contracts. Attachment 3 contains more information on discretionary and non-discretionary operations.

Pursuant to the proposed operating regime, Reclamation will attempt to meet the desired spring peak, minimum duration, and base flow targets at Whitewater and below the Redlands Diversion.

The new operation plan makes releases that attempt to meet a spring peak target at the Whitewater gage at the time the North Fork of Gunnison River is near its peak (generally May 15 to May 31). Peak targets at Whitewater are based on the May 1 or May 15 “April through July forecast” of Blue Mesa unregulated inflow. The forecast is provided by the National Weather Service through the Colorado Basin River Forecast Center starting in January and is updated twice per month until the end of July.

Attachments 8 and 9 and Section 6.0 of this report summarize modeled results of the proposed action.

Operations are described on a seasonal basis:

- **January-March:**

Water would be released based upon the most recent April-July inflow forecast and downstream water demands with the goal of achieving a March 31st Blue Mesa Reservoir content target (determined from the January, February, and March 1st forecasted April-July Blue Mesa inflow) and with a goal of higher releases during January for power purposes. The March 31st target is intended to optimize Aspinall Unit operations for storage, flood control, and hydropower production.

The proposed action sets a minimum downstream release for instream flow, generally 300 cfs, but can be higher based on the previous year's operations that consider factors such as the fall brown trout spawn or downstream senior water rights. Maximum releases are limited to the 2,150 cfs Crystal powerplant capacity in most years. Generally the above release patterns would meet downstream base flow needs for endangered fish; if not, releases will be adjusted accordingly. Crystal releases will reregulate peaking releases from Morrow Point throughout the year to produce stable downstream flows.

- **April-July :**

Reclamation will not bypass the powerplant at Crystal Dam from April 1 through May 10, thus making more water available for a spring peak and/or duration flows (however, in order to reduce flooding risk, Reclamation may bypass the powerplant during this time period if Blue Mesa's forecasted inflow indicates that the Year Type is in a "Wet" category). This has the effect of holding water for 40 days that may have been bypassed unnecessarily if the runoff was over-forecasted that year. In addition to making water available for peak releases it also may improve the chance of filling Blue Mesa, with a slight risk of increasing flood frequency at Delta.

Peak releases will generally be made after May 10th and before June 1st in an attempt to match the peak from the North Fork in order to maximize the potential of meeting the desired peak at Whitewater. However, this timeframe could be altered to May 1-June 15 if appropriate for endangered species and other resource concerns. Crystal releases, and releases from Morrow Point and Blue Mesa as needed, would begin to be ramped up approximately 5 days prior to the predicted North Fork peak. Releases may be reduced in an attempt to reduce flooding if the Gunnison River at Delta approaches 14,000 cfs.

The magnitude of the desired peak at Whitewater is determined based on the "Year Type" category, as defined in the Flow Recommendations, in conjunction with the most recent forecast information as shown in Figure 1 and Table 3. Releases will be made from the Aspinall Unit using the necessary combination of available powerplants, bypasses and spillways, while attempting to reach the spring peak target. Reclamation's ability to meet a desired peak is limited by the physical constraints/availability of the Aspinall Unit outlet features in some years. For example, Blue Mesa water elevation may not be high enough to use its spillway.

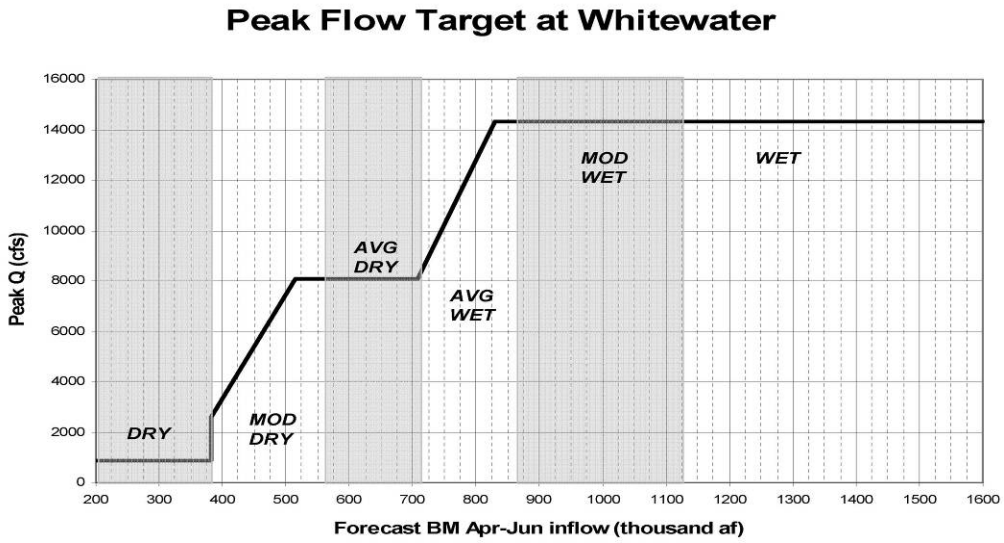


Figure 1. Determination of peak flow target

Table 3. Spring peak and duration targets for range of forecasted inflow.

Blue Mesa Forecasted Inflow	Peak Target @Whitewater	Duration of Half Bank (8,070 cfs)	Duration of Bankfull (14,350 cfs)
Acre-feet	cfs	Days	Days
< 381,000	900	0	0
381,000 to 516,000	2,600 to 8,070	0	0
516,001 to 709,000	8,070	10	0
709,001 to 831,000	8,070 to 14,350	20	2
831,001 to 1,123,000	14,350	40	10
> 1,123,001	14,350	60	15

After a peak flow release is made, high releases may continue in an attempt to maintain flows at half bankfull or bankfull levels. Releases for duration of higher flows in conjunction with the desired peak at Whitewater will be made if it is possible to reach 90 percent of the desired peak. The length of duration of flows is dependent on the "Year Type" category in the Flow Recommendations (see Tables 2 and 3). Minimum duration is targeted and may be exceeded at times.

- **August-December:**

Releases will be set utilizing the most recent forecast of August through December inflow and downstream senior water demands, with the goal of having Blue Mesa Reservoir at or below an elevation of 7,490 feet (580,000 af of live storage) by December 31st to minimize upstream icing. The minimum release criteria of 300 cfs for

downstream resources will still apply, in addition to existing downstream senior water right demands (meaning that Blue Mesa will not store that portion of water needed to satisfy downstream senior water rights).

- **Ramping**

Ramping guidelines for release changes under the proposed action are as follows:

-Daily ramping rates on the ascending limb will be the maximum of 500 cfs or 25% of flow in Black Canyon on the previous day. Ramping can be accomplished with more than one change per day.
-Daily ramping rates guidelines for the descending limb will be the maximum of 400 cfs or 15% of flow in the Black Canyon on the previous day. Ramping can be accomplished with more than one change per day.
-Ramping up will begin 5 days prior to the estimated peak flow date on the North Fork Gunnison River.

- **Base flows**

Base flows are provided under the proposed action and can vary under different hydrologic conditions. Additional releases to maintain minimum base flows at Whitewater will be set each year based on discussions with the Service. In most years, a base flow of 1,050 cfs will be maintained at the Whitewater gage; however, this target will be reduced in dry or moderately dry years.

Table 4 summarizes base flow targets as outlined in the Flow Recommendations. As footnoted, additional releases will be made to provide 100 cfs to the Redlands Fish Ladder as needed in April through September and 40 cfs for the Redlands Fish Screen from March through November, using storage water if necessary. Base flows would normally provide adequate migration flows downstream from the Redlands Diversion.

Table 4. Base flow targets (cfs) at Whitewater Gage under the proposed action.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet	1050	1050	1050	1050	1050	1500	1500	1500	1050	1050	1050	1050
Mod Wet	1050	1050	1050	1050	1050	1500	1500	1500	1050	1050	1050	1050
Avg Wet	1050	1050	1050	1050	1050	1500	1500	1050	1050	1050	1050	1050
Avg Dry	1050	1050	1050	1050	1050	1500	1500	1050	1050	1050	1050	1050
Mod Dry*	750	750	750/790	750/890	750/890	1050	1050	1050	750/890	750/790	750	750
Dry*	750	750	750/790	750/890	750/890	1050	1050	750/890	750/890	750/790	750/790	750

* During March through November in Moderately Dry and Dry type years, additional releases will be made as necessary to provide flows, above the 750 cfs anticipated to be diverted by the Redlands Water and Power Company, for the fish ladder and fish screen as shown.

- **General**

Attachment 11 summarizes many of the general guidelines for operations that will continue under the proposed action.

2.2 Adaptive Management

Adaptive management is a systematic approach for improving resource management by learning from management outcomes. Adaptive management promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become understood. Essentially, the long-term responses of endangered fish to new operations and other Recovery Program actions are uncertain and future monitoring will be needed to make adjustments in implementing operations and the overall Recovery Program.

Uncertainties of endangered fish response to management actions exist throughout the Recovery Program and adaptive management principles are integral to addressing them. The Recovery Program acts both as a scientific clearing house on the technical side of adaptive management and as a vehicle for agencies (such as the state of Colorado, Western Area Power Administration, Reclamation, the Service, and others) to identify and coordinate research and monitoring in the presence of other stakeholders.

There are uncertainties related to the response of endangered fish populations and critical habitat to the flow modifications proposed under the preferred alternative for Aspinall Unit reoperation. For that reason, the Flow Recommendations Report (McAda 2003) suggested using adaptive management principles, including monitoring responses of fish and their habitat to the new flow regime, to address uncertainties.

Uncertainties identified in the Flow Recommendations Report by McAda (2003) include:

- Determination of the amount and location of floodplain habitat necessary for recovery of species.
- Determination of relationship of reproductive success of pikeminnow and humpback chub to increased spring flows. Effect of new flow regime on non-native fishes that adversely affect native fish.
- Determination of the frequency (recurrence interval) and duration (number of days) that flows need to exceed half bankfull and bankfull discharge to maintain habitats required by the endangered fishes.
- Determination of response of primary and secondary production in the rivers to new flow regime.
- Consideration of the trade-off between high spring flows and base flows needed during the mid-to late summer.

Other uncertainties include whether elevated selenium concentrations and other water quality elements affect the recovery of the endangered fish in the Gunnison and other basin rivers. As discussed in Section 3.4.3 of this PBA, the effect of selenium levels on

fish recovery in the Gunnison and Colorado rivers is not clear. Long-term trends in selenium concentrations have not been determined. Clarifying these effects is a necessary first step in addressing these uncertainties.

Reclamation and the Service will work together and with the Recovery Program to develop study plans to evaluate endangered fish populations and their habitat and their response to the new flow regime. This coordination will occur within one year of the finalization of the biological opinion and Record of Decision on the reoperation. Reclamation and the Service will also work through the Recovery Program to implement the study plans**.** This would include (1) identifying appropriate monitoring and research to evaluate effects of Aspinall reoperation and (2) including these activities in the Recovery Program's RIPRAP as necessary to identify the potential for modifying or refining flows from the Aspinall Unit. These plans may include research-driven requests for flows to answer questions identified in the study plan.

New information developed by the Recovery Program from these activities will be presented to Reclamation to determine operational flexibility available to address the new information. It is expected that any refinements in operation of the Aspinall Unit would be within the scope of the current proposed action and that implementation of refinements would occur with appropriate Section 7 consultation as necessary.

2.3 Extreme Conditions, Maintenance, and Emergencies

Flow recommendations address dry years by basing peak flow and duration targets on annual inflow conditions. Also in severe drought years such as 1977 and 2002 no special peak releases are targeted for endangered fish. Dry year peaks are only 900 cfs. Severe droughts, with anticipated shortages to Aspinall Unit water uses, will be responded to through shortage sharing. Operational changes could include temporary modifications to normal operations of the reservoir and potential short-term modifications in the target flows in the proposed operation. In periods of extreme, multi-year droughts, releases from the Aspinall Unit may have to be reduced to match the inflow to the reservoir during part of the year.

The proposed action would include certain specific drought rules:

- In Wet, Moderately Wet, and Average Wet years following a Dry year in which the previous December 31 Blue Mesa content was less than 522,300 af and if March 31 content is less than 400,000 af, half bankfull targets are reduced to the next lower category.
- During Dry and Moderately Dry years, if Blue Mesa content drops below 600,000 af, Whitewater base flow target is reduced from 1,050 cfs to 900 cfs until Blue Mesa content exceeds 600,000 af.
- If a Moderately Dry year follows a Dry or Moderately Dry year, decrease peak target to 5,000 cfs if Blue Mesa content is less than 400,000 af on March 31 or April 30.

Operations at the Aspinall Unit may be modified due to special maintenance or replacement needs which may limit outlet capacities or require special downstream flows for repairs and inspections. Special flows may also be needed at some time in the future for repairs or replacement of the Gunnison Tunnel Diversion Dam, located a short distance downstream from Crystal Dam.

Emergencies are not predictable but may be associated with dam safety, personal safety of individuals or groups associated with recreation or other activities on the river, power system conditions, or releases of oil, hazardous substances, pollutants, or contaminants. Emergencies associated with dam safety could include unforeseen high or low releases or operations to protect dam structures. Emergencies with the safety of individuals may be associated with river rescue or recovery operations. Power emergencies could include insufficient short-term generation capacity, transmission maintenance, and other factors. Emergency operations are typically of short durations as a result of emergencies occurring at the dam or within the transmission network. In the case of emergencies, Reclamation will immediately address the problem and then comply with 50 CFR Section 402.05 emergency procedures.

2.4 Coordination of Operations

Reclamation will continue to conduct Aspinall Unit operations meetings 3 times per year. The purpose of operation meetings-- held in January, April, and August-- is to share information between Reclamation and Aspinall stakeholders regarding issues in the Gunnison Basin related to the operation of the Aspinall Unit. The meetings are used to coordinate activities among agencies, water users, and other interested parties concerning the Gunnison River. Reclamation considers the information exchange at these meetings in preparing operation plans for the Unit. The projected operation of the Aspinall Unit is used by Reclamation in the development of the overall 24-month Study, a comprehensive planning model for the operation of Reclamation projects in the Upper and Lower Colorado River Basins, and includes operating plans for Glen Canyon, Flaming Gorge, and Navajo Units, as well as the Aspinall Unit. Operation of the Aspinall Unit considers projected hydrologic factors, authorized unit purposes, existing water rights, target elevations for reservoirs, implementing the preferred alternative for endangered fish, and other factors.

Reclamation will communicate with appropriate agencies and organizations prior to scheduled operation meetings or as needed to gather information useful in developing proposed operation plans to be presented at operation meetings.

2.5 Other Elements of the Action

The proposed action includes the continuation of the operation of other Reclamation Projects in the Gunnison Basin as listed in Section 1.3. Operation of these projects would continue by water districts or associations under contract with Reclamation.

In addition, private, local, and state water projects and uses in the Gunnison Basin would continue. As with the Aspinall Unit, construction and past operations of facilities for these water uses is part of the environmental baseline and non-discretionary.

It is estimated that depletions from the Gunnison River above the Whitewater gage averaged 428,348 af over the 1975-2005 period (Reclamation 2008). Approximately 95% of these depletions result from irrigation and 5% from domestic and industrial water use and reservoir evaporation.

In this assessment, new depletions of 3,500 af, primarily in the North Fork Basin, are also addressed along with full development of the Dallas Creek Project (17,200 af) and use of 30,800 af of subordination water in the Upper Gunnison Basin. The new depletions of 3,500 af are not specifically identified but will most likely be related to residential development in the basin. Additional information on other water uses is found in Section 3.3.

In total, depletions under the proposed action would range in the 450,000-500,000 af. Table 5 summarizes the depletions under the proposed action.

Table 5. Estimated average annual depletions in the environmental baseline.

Project	Estimated average annual depletion (af)
Aspinall Unit	10,000
Uncompahgre Project	155,000
Dallas Creek Project	17,200
Paonia Project	10,000
Smith Fork Project	6,000
Bostwick Park Project	4,000
Fruitgrowers Project	4,100
Other water uses	210,000-260,000
Dolores Project	99,200*
Upper Gunnison Subordination	30,800 (maximum rather than average depletion)
Total for Gunnison Basin (excludes Redlands)	450-500,000 af

*The original Dolores Project ESA consultation addressed a 131,000 af depletion. Updated information indicates actual depletions are approximately 99,200 af. For ESA purposes, return flows to the San Juan Basin were considered depletions.

2.6 Conservation Measures

In addition to re-operating the Aspinall Unit, Reclamation will continue to support the Recovery Program and will continue to support efforts to improve water quality in the Gunnison River and downstream.

Public Law 106-392 authorizes the Bureau of Reclamation to provide up to $6 million per year (adjusted for inflation) of CRSP power revenues to partially meet the base funding needs of the Recovery Program and the San Juan River Recovery Program. Additional funding is provided by the participating States and the Service. Base funding provides for operation and maintenance of capital projects, implementation of recovery actions other than capital projects, monitoring and research to evaluate the need for or effectiveness of recovery actions, and program management to carry out the Programs. Reclamation will continue to support these activities as authorized by P.L. 106-392 as amended as well as subsequent legislation.

Adaptive management (Section 2.2) is considered a conservation measure and will allow flexibility in operations to respond to new information on the species.

A Selenium Management Program will also be developed that addresses potential selenium impacts on endangered fish species in the Gunnison and Colorado rivers (see Section 3.4.3 for potential effects). The Selenium Management Program will incorporate and continue ongoing selenium reduction efforts in the Uncompahgre Valley and other areas of the Gunnison Basin and will add several new elements to ensure the future effectiveness of the program. The overall long-term goal of the program is to assist in species recovery per the Recovery Goals. Elements of the Selenium Management Program include:

- Accelerated implementation of salinity/selenium control projects for irrigated agriculture
- Reduction of other non-point source selenium loading
- Technology development
- Water quality monitoring
- Monitoring of endangered fish populations
- Coordination with lower Gunnison River Basin watershed management plan
- Regulatory support
- Public information and education
- Adaptive management
- Institutional support

A final Selenium Management Program, including timeframes and goals, will be developed within 18 months of issuance of the programmatic biological opinion. This timeframe allows monitoring data and other information collected in the first year to be used to refine the plan. During this period, ongoing projects that reduce selenium will continue.

Reclamation’s vision for the program involves a cooperative effort with the substantial involvement of stakeholders. Reclamation will request annual Federal funding subject to appropriations (in addition to existing Salinity Control Program funding under the Colorado River Basin Salinity Control Project [CRBSCP] Act). Keys to success are the support and participation of basin water users for selenium reduction measures and

improved management of water and land resources. With limited Federal budgets, local support and participation are critical elements to achieving success.

The development of the Selenium Management Program will focus on the lower Gunnison River and will pay particular attention to the Uncompahgre Valley. The Selenium Management Program will involve the established Selenium Task Force participants, federal agencies, water users, and state, county, and local government agencies. Because the Program will involve many interests and parties, formal documentation and funding mechanisms will be developed over the 18 month period following issuance of the programmatic biological opinion by the Service. Implementation will begin immediately with completion of the programmatic biological opinion, and implementation of all aspects of the Selenium Management Program not already underway will begin within 5 years of issuance of the opinion for the Gunnison River Basin in accordance with a Long Range Plan to be prepared.

The Selenium Management Program Long Range Plan will include identification of specific cost effective selenium reduction measures, high priority implementation locations, implementation schedule, benchmarks, responsible entities, monitoring needs, and coordination with ongoing Recovery Program activities. The Selenium Management Program will define funding and other resources needed for implementation, including commitments by Reclamation, the State of Colorado, water users, local governments and other parties. The Long Range Plan will be formatted similar to the Recovery Program's Recovery Action Plan and will be updated annually. Progress in implementing the Long Range Plan will serve as the benchmark for evaluating progress in implementing the Selenium Management Program.

Implementation of a Selenium Management Program in the Lower Gunnison River basin will be based on the best available information that focuses actions toward the recovery of razorback sucker and Colorado pikeminnow. Initially, this means that efforts will be made to reduce selenium loading in a timeframe complimentary to Recovery Goal timelines for razorback sucker and Colorado pikeminnow.

The ultimate objective of this Program is to meet the Recovery Goals for razorback sucker and Colorado pikeminnow (2002; currently being updated by the FWS); thus, additional selenium reduction efforts may continue and expand per the Program timelines. Once self-sustaining, recovered populations per the Recovery Goals have been attained, further selenium reduction efforts could be discontinued as long as new agreements are developed to maintain the selenium remediation measures that had contributed to the recovery of the subject species.

The Selenium Management Program will include the elements described below:

A. Accelerated Implementation of Salinity/Selenium Control Projects for Irrigated Agriculture: The salinity/selenium control projects implemented to date are described in Section 3.4.3. Future implementation is described below.

It is anticipated that the majority of reductions in selenium loading will be accomplished via the CRBSCP, NRCS Environmental Quality Incentives Program (EQIP) and grant-funded Task Force activities. Continuing implementation of CRBSCP projects is dependent on a competitive selection process. Uncompahgre Project proposals in the area of most concern are expected to remain cost competitive; however, more costly projects may require supplemental funding.

In the past, supplemental funding for Uncompahgre Project irrigation system improvement proposals was provided by the National Irrigation Water Quality Program (NIWQP), Congressional "write-ins" for selenium control, and EPA Section 319 funding. As shown in Table 5 in Section 3.4.3, supplemental funding provided about $1 for every $2 from the CRBSCP for initial irrigation system improvements (Phases 1-4). Although this amount of supplemental funding has traditionally been required to make Uncompahgre Project lateral piping projects more competitive under CRBSCP, the Program's current competitive cost range is increasing and recent Uncompahgre Project proposals have been found to be cost effective absent supplemental funding.

In the future, supplemental funding to augment CRBSCP funding for the more costly canal lining and pipe replacement of large laterals will be provided by Reclamation, subject to appropriations, and may be further complimented by state funds and various grant funding opportunities. Reclamation will seek supplemental funding (subject to appropriation) to assist in implementing all facets of the Selenium Management Program. Portions of this funding will be used to implement agriculture-related projects as well as the other activities as described in items B through J below.

Three phases of salinity/selenium control projects have been implemented or are underway in the Uncompahgre Valley. The recently funded Phase 4 includes an additional 11.4 miles of lateral lining in high priority selenium reduction areas, bringing the total length of laterals completed or under contract to 51 miles. This phase is presently scheduled to be completed by 2012. Approximately $2.8 million will be available for implementation of Phase 4, $2 million from the Salinity Control Program and $800,000 from the Environmental Protection Agency's (EPA) 319 grant program. Phase 4 is expected to reduce salinity loading by 3,650 tons/years and selenium loading by 70 to 360 pounds/year.

It is anticipated that the development of the Selenium Management Program will include advanced planning to outline future CRBSCP proposals involving larger scale lateral piping and possibly canal lining projects in the Uncompahgre Valley that should provide more rapid selenium loading reductions to the lower Gunnison River. With approximately $2 million/year (in current dollars) for lateral piping, Uncompahgre Project managers estimate that they could install approximately 10 miles of laterals each year on the east side of the Uncompahgre Valley. This commitment, subject to appropriations, exceeds current average construction rate of 5 miles/year. With more dependable funding, equipment could be purchased and a crew could be working year around on installation of pipe. Given sufficient resources, it is estimated that all remaining laterals and small canals in the planned East Side (of Uncompahgre Valley)

Laterals Project could be piped in approximately 15 years or by 2024 if the biological opinion is completed in 2009. This additional 151 miles of pipeline will reduce salt loading by approximately 50,000 tons/year and selenium loading by 1,000 to 5,000 pounds/year at a total cost of $35 to $40 million (in current dollars). Canal lining in the highest selenium loading sub-basins will also be investigated in the development of the Selenium Management Program. Lining a major delivery canal such as the Selig Canal through the Loutzenhizer Arroyo drainage could be expected to reduce salinity loading by an additional 400 to 500 tons/mile/year and associated selenium loading by an additional 10 to 50 pounds/mile/year.

Other Lower Gunnison basin salinity/selenium projects, outside the Uncompahgre Project service area will be incorporated into the Selenium Management Program if determined to be viable and necessary.

In addition to increasing water delivery system efficiency by piping laterals and lining of canals, future salinity/selenium control measures will focus on a) increasing near-farm water delivery system efficiency by installing pipelines, b) increasing on-farm irrigation efficiency by installing high efficiency systems such as sprinkler and drip systems and c) encouraging other more efficient irrigation practices and measures to reduce deep percolation of water that results in reductions of selenium loading to the lower Gunnison River. This component will be accomplished via the NRCS EQIP and the recently created Basin States Salinity Control Program.

Reclamation will work with water providers, conservation districts and NRCS to promote on-farm salinity control projects to reduce seepage losses and deep percolation from irrigation practices in areas with known high selenium loading rates. To the extent possible, Reclamation will work with NRCS to prioritize the funding of EQIP projects in high selenium loading areas of the basin. Such targeted efforts have been documented to result in more cost effective non-point source control proposals by controlling ‘two contaminates for the price of one’. Utilizing this approach may further improve Lower Gunnison projects cost effectiveness under the CRBSCP.

Reclamation will support funding from any source that might accelerate selenium control efforts, consistent with applicable federal, state and local laws.

B. Reduction of Non-Point Source Selenium Loading from Developing Areas: To accelerate efforts to reduce selenium loading from urbanizing areas, Federal and State agencies and basin water users will enhance their level of participation in the Task Force. Reclamation and others will provide additional technical, financial, and administrative assistance so that the Task Force can achieve the following:

- identify and encourage implementation of Best Management Practices to minimize selenium loading to the lower Gunnison River associated with urban and suburban development activities;
- discourage the construction of unlined ponds and/or water features in pervious selenium rich soils;

- work with local governments, responsible for land use planning, to minimize new selenium loading by avoiding housing and industrial developments which utilize leach fields or outdoor irrigation in areas with high selenium loading potential, such as previously unirrigated lands;
- support local government requirements to convert irrigation delivery systems from open channel to piped systems in urbanizing areas;
- support local government implementation of development codes which encourage native landscaping, limit irrigated landscape areas, and/or require efficient landscape irrigation systems on selenium rich lands;
- increase educational programs for better understanding of selenium issues and acceptance of appropriate solutions; and
- support general water conservation programs for all outdoor water uses (lawns, golf courses, septic systems, etc.), including public education efforts to promote more efficient water use and minimization of deep percolation.

C. Technology Development: Reclamation will utilize its Science and Technology Program, to the extent possible, to explore new technologies for reducing selenium loading and/or remediating drainage water with elevated selenium concentrations. The technologies to be reviewed for feasibility include development of approved flocculating agents that can potentially be extremely cost effective and can be implemented quickly to reduce seepage and selenium loading, bioreactors, and other technologies to cost effectively treat selenium-rich waters.

D. Water Quality Monitoring: Federal, state and local entities will partner to monitor selenium concentrations in the lower Gunnison River and its tributaries in order to better understand selenium loading mechanisms, quantify selenium loading reductions and establish selenium loading trends over time.

Although, selenium concentrations in the lower Gunnison Basin have been monitored for years, current water quality monitoring for selenium on a regular basis is occurring only at two stations: Uncompahgre River at Delta (Colorado Department of Public Health and Environment, quarterly sampling) and Gunnison River near Grand Junction (USGS and Colorado Department of Public Health and Environment). Water quality monitoring for selenium has previously occurred at Gunnison River at Delta, Gunnison River below the Gunnison Tunnel, Uncompahgre River at Colona, and North Fork of the Gunnison River near Somerset.

The Colorado River Water Conservation District is working on a proposal to expand selenium and flow monitoring by installing real-time specific conductance monitors and gage stations to help define relationships between selenium and total dissolved solids. Proposed monitoring includes samples for major ions and dissolved selenium, as well as flow. The sites under discussion include:

- Gunnison River below Gunnison Tunnel (above selenium loading areas)
- North Fork of the Gunnison River at its mouth
- Gunnison River at Delta

- Uncompahgre River at Colona (above selenium loading areas)
- Uncompahgre River at Delta

Depending on the level of monitoring, cost estimates, exclusive of initial gage installation costs, range from $40,500-$118,000/year.

The Colorado River Water Conservation District is developing cost sharing arrangements. The resulting final monitoring program will be included in the Selenium Management Program.

E. Monitoring of Endangered Fish Populations: The Recovery Program experimentally stocked razorback sucker in the lower Gunnison River (i.e., downstream of Delta) during the mid-1990's and initiated an integrated stocking plan in 2003. Operation of the fish ladder at the Redlands Diversion Dam on the lower Gunnison River began in 1996 and restored access to 50 miles of critical habitat for the endangered fishes. The Recovery Program periodically conducts fish surveys in the lower Gunnison River. Over the past several years, those surveys have included sampling to determine if razorback sucker and Colorado pikeminnow are reproducing in the lower Gunnison River. Larvae of both species have been found, and survival of razorback sucker larvae through the first year is evidenced by collections of juveniles (it is uncertain whether these juveniles were stocked as larvae or produced from reproduction by stocked adults). The Recovery Program monitors the Colorado pikeminnow population in the Upper Colorado River Subbasin to develop population estimates for the purpose of tracking progress toward achieving the Subbasin demographic Recovery Goal criteria. This monitoring includes the Gunnison River downstream of the Redlands Diversion Dam and incorporates fish using the fish ladder.

The Recovery Program is developing a basin-wide razorback sucker monitoring program that will include monitoring of all life stages. Design of the monitoring program is expected to be completed in fiscal year 2009. Implementation will begin in 2010. It will include multi-life stage monitoring on the lower Gunnison River. Eventually, population estimates will be developed for razorback sucker that will include fish in the lower Gunnison River.

Results of future fish surveys, ongoing population estimates for Colorado pikeminnow, and the future monitoring program for the razorback sucker will provide the basis for determining the status of Colorado pikeminnow and razorback sucker in the lower Gunnison River. This information will be used to measure the success of recovery efforts and perhaps the effects of the Selenium Management Program and will be incorporated into the adaptive-management process to determine factors limiting recovery of Colorado pikeminnow and razorback sucker

F. Coordination with Lower Gunnison River Basin Watershed Management Plan: The Selenium Task Force is developing a Watershed Management Plan (WMP) for the lower Gunnison River Basin. The WMP will focus on remediation of selenium with the goal of meeting the 4.6 parts per billion (ppb) water quality standard. Any organization

addressing remediation planning within the watershed may utilize the WMP for planning purposes. The objective of the WMP, once adopted, is to guide, direct, and prioritize 319 Grants from EPA to specific projects within the watershed. The WMP will identify causes and sources of water quality impairment, estimate load reductions, and describe nonpoint source management measures, identify technical and financial assistance needed to carry out the WMP, provide an implementation schedule, define an education and outreach program, develop milestones for determining progress, set criteria to measure selenium load reductions, and develop a monitoring program to determine effectiveness of implementation efforts.

The Task Force will complete the watershed management plan by September 1, 2010. WMP development is supported by 319 Grant funds ($32,479) and local matching funds ($23,020). Development of the WMP will guide and direct future 319 Grants to high priority selenium reduction areas in the Gunnison Basin and provide a source of funding for a number of activities in the Selenium Management Program.

G. Regulatory Support: Reclamation will consider selenium loading as a factor in its NEPA/ESA review of any proposed new irrigated lands associated with Reclamation projects in the basin. The Bureau of Land Management will be encouraged to fully consider possible ramifications of any land transfers or exchanges on selenium loading and implement restrictions where any increases are possible.

H. Public Information and Education: Reclamation will provide staff support for implementation of a public information and education element as part of the Selenium Management Program.

I. Adaptive Management: An adaptive-management component will be described in the final Selenium Management Program. It will include annual review of progress and reporting to the Service, annual updating of the Long Range Plan, a periodic review of the effectiveness of ongoing selenium reduction measures, water quality monitoring data, and status of endangered fish, followed by adjustments in the Selenium Management Program as needed. To ensure transparency, the process will be formalized in terms of timing of reviews, procedures, and development of reports for publication that include recommendations for modification of the Selenium Management Program as needed.

J. Institutional Support: Development and implementation of the Selenium Management Program and its associated Long Range Plan is a significant responsibility. There will be a need for oversight of the implementation of the Selenium Management Program and the Long Range Plan, annual update of the Long Range Plan, coordination of activities, reporting of progress on Selenium Management Program implementation, and coordination of the adaptive management process. It is recommended that the Task Force assume a significant share of responsibilities, with substantial institutional and financial assistance from Reclamation, Colorado River Water Conservation District, State of Colorado, the Service, and other parties involved in the Task Force.

Reclamation will have primary responsibility for development of the Selenium Management Program and the Long Range Plan. Coordinating implementation of the Selenium Management Program and Long Range Plan is recommended to be the responsibility of the Task Force. The Task Force would have ongoing responsibilities for tracking implementation of the Long Range Plan, agreements and attainment of funding. The Task Force – and its staff – would not be responsible for implementation of the Selenium Management Program, but would have responsibilities for oversight, monitoring, and reporting. In addition, the Task Force would be responsible for facilitating modifications to the Selenium Management Program and the Long Range Plan, based on recommendations developed through an adaptive management process.

Reclamation will be responsible for implementation of the piping of laterals, subject to appropriations. Reclamation will also be responsible for implementation of more costly canal lining and pipe replacement of large laterals should the Selenium Management Program determine these methods effective. Reclamation will implement effective selenium reduction subject to appropriations and supplemental funding provided by state and grant programs.

2.7 Authority

The PBA is prepared in accordance with Section 7 of the ESA of 1973, as amended (16 U.S.C. 1531et seq.).

The following paragraphs describe the Department of the Interior's basis and authority for implementing the new operations at the Aspinall Unit. The authority to implement the operations is found in Section 1 of CRSPA. This section states:

> In order to initiate the comprehensive development of the water resources of the Upper Colorado River Basin, for the purposes, among others, of regulating the flow of the Colorado River, storing water for beneficial consumptive use, making it possible for states of the Upper Basin to utilize, consistently with the provisions of the Colorado River Compact, the apportionments made to and among them in the Colorado River Compact and the Upper Colorado River Basin Compact, respectively, providing for the reclamation of arid and semi-arid land, for the control of floods, and for the generation of hydroelectric power, as an incident of the foregoing purposes, the Secretary of the Interior is hereby authorized (1) to construct, operate, and maintain the following initial units of the Colorado River storage project, consisting of dams, reservoirs, powerplants, transmission facilities and appurtenant works…

The Colorado River Compact of 1922 established an Upper Basin and a Lower Basin within the Colorado River system and apportioned the exclusive beneficial consumptive use of Colorado River water in perpetuity to the Upper and Lower Basins. The Upper Colorado River Basin Compact of 1948 apportioned the Upper Basin's share of the Colorado River system among the states of Colorado, Utah, Arizona,

Wyoming, and New Mexico. CRSPA was enacted in 1956 to facilitate the development of the water and power resources of the Upper Basin consistent with the Compacts.

The Recovery Program (Section 2.8) was developed to facilitate the continued development of states' Compact apportionments in light of ESA concerns. The goal of the Recovery Program, therefore, is to conserve the Gunnison and Colorado rivers populations of endangered fish species consistent with the recovery goals of the species published by the Service, while proceeding with the continued operation and development of water resources of the Colorado River Basin. All Recovery Program participants, agreeing that recovery to the point of de-listing will both facilitate and insure the continued development of water resources, have agreed with the principles and goals of the Recovery Program through their participation in and support of program activities. In addition to its recovery objectives, the Recovery Program includes an agreement on principles for conducting ESA Section 7 consultations, wherein program actions and sufficient progress toward recovery constitute a Reasonable and Prudent Alternative for existing and future water resource management and development activities that are likely to jeopardize the continued existence of endangered fish species or cause the destruction of or adverse modification of critical habitat of those species.

The Flow Recommendations for the Gunnison River, in concert with other program actions, are intended to avoid jeopardy and assist in recovery. By implementing actions that assist in meeting the Flow Recommendations, Reclamation is taking the steps necessary to avoid jeopardizing the continued existence of the endangered fish from the operation of the Aspinall Unit and to voluntarily and cooperatively take steps to facilitate recovery of the fish, which, in turn, will support the continued and further utilization of the Federal facilities to aid in the development of the states' Compact apportionments. Thus, consistent with the authorized purposes of CRSPA, implementation of the proposed action supports the States in the utilization of their Compact apportionment while assisting in the recovery of endangered species. Moreover, that specific authorized purposes of the Aspinall Unit may not be fully maximized for limited durations in certain year types does not invalidate the actions of the Secretary, as long as the overall purposes of CRSPA are met and we expect in this instance, these purposes will be met.

This action is limited to the proposition that both avoiding jeopardy and making progress toward recovery of listed fish facilitate the ability of the Upper Basin states to continue utilizing and further developing their Colorado River apportionments. In these particular and unique circumstances, therefore, we conclude the implementation of an operations regime that is consistent with the proposed alternative is deemed to be within the authorization contained in Section 1 of CRSPA.

2.8 Upper Colorado River Endangered Fish Recovery Program

The Recovery Program involves federal, state, and private organizations and agencies in Colorado, Utah, and Wyoming with a common goal of recovering endangered fish and

providing for present and future water uses in the Upper Colorado River Basin. The program involves several elements:

- Improving river habitat-protecting and improving floodplains, constructing fish passages, installing fish screens in canals
- Conducting research-studying the fish and their habitat, monitoring
- Providing adequate streamflows-manage releases from upstream reservoirs, improve efficiency of existing uses, modify timing and magnitude of releases from major reservoirs
- Managing non-native fish species-stocking agreements, control escapement from reservoirs, remove selected species from critical habitat
- Stocking-establish hatcheries and growout ponds, establish refugia ponds, reestablish populations

In cooperation with the Recovery Program, Reclamation has operated the Aspinall Unit to provide research flows in the lower Gunnison River. Research and monitoring studies have been completed on the Gunnison River, including biological investigations, river morphology studies, and water temperature studies. Monitoring of endangered fish populations and reproduction and recruitment are continuing. Habitat studies continue through U.S. Geological Survey sediment movement studies. A fish ladder has been constructed around the Redlands Diversion and a fish screen installed in the Redlands Canal. Water has been supplied to operate the fish ladder and screen. Backwater improvements and protection and floodplain conservation easements have been made near Delta and Whitewater and are monitored; and Colorado pikeminnow and razorback suckers have been stocked in the Gunnison and this stocking will continue.

In addition studies have been completed on the Colorado River in Colorado and Utah and on its major tributaries, and backwater improvement/ protection and fish passages and fish screening have been completed. Research, stocking and monitoring programs continue.

In order to define and clarify processes of the Recovery Program, a Section 7 Agreement and a Recovery Implementation Program Recovery Action Plan (RIPRAP) were developed (Fish and Wildlife Service 1993) and updated annually. The Agreement established a framework for conducting Section 7 consultations on depletion impacts related to new projects and impacts associated with existing projects in the Upper Basin. Activities and accomplishments under the Recovery Program are intended to provide the reasonable and prudent alternatives which avoid the likelihood of jeopardy to the continued existence of the endangered fish resulting from depletion impacts of new projects and all existing or past impacts related to historic projects with the exception of the discharge by historic projects of pollutants such as trace elements, heavy metals, and pesticides.

Procedures outlined in the Section 7 Agreement are used to determine if sufficient progress is being accomplished in the recovery of endangered fishes to enable the Recovery Program to serve as a reasonable and prudent alternative to avoid the likelihood

of jeopardizing and/or adversely modifying critical habitat. The RIPRAP presents specific recovery actions such as providing instream flows, constructing and operating fish passages and fish screens, controlling non-native fishes, and propagating and stocking endangered fish. The Gunnison River portion of the Recovery Plan includes 63 individual actions, 78% of which are completed or ongoing. One remaining high priority action is to operate the Aspinall Unit to improve conditions for downstream endangered fish.

2.9 ESA Consultation History

Consultation on the operation of initial units of the Colorado River Storage Project was deferred in the 1980's pending completion of hydrologic, biological, and other studies. Construction of the units occurred prior to passage of the ESA. At the present time, consultations have been completed on the operations of Flaming Gorge Dam and Reservoir and Navajo Dam and Reservoir and operations of these features have been modified to improve habitat conditions of the endangered fish.

There are several ESA consultations related to the present Aspinall Unit consultation and the Gunnison Basin:

> Dallas Creek Project Biological Opinion--"The most serious problem posed by the Dallas Creek Project and related water developments is the loss of water from the Gunnison River and the Colorado River. We know of only one alternative which would allow the proposed project to be constructed and operated without jeopardizing the Colorado squawfish and the humpback chub. That alternative is the release of water from the Dallas Creek Project or from other projects that regulate flows in the Gunnison River and the Colorado River in order to replace the depletions caused by the Dallas Creek Project. This released water could provide for essential life stages of the endangered fishes. The Curecanti (Aspinall Unit) Project may be the best source of water for such releases….The Dallas Creek Project would deplete 17,200 acre-feet of water in an average year. To compensate for this loss of water from the river system, it may be necessary that an equal volume be released to the Gunnison River from one or more projects…However, our studies may reveal that flow releases totaling less than 17,200 acre-feet annually are adequate for the fishes to survive in the areas and in the numbers that we believe necessary for recovery" (Fish and Wildlife Service 1979).
>
> Dolores Biological Opinion--"…only one alternative which would allow the proposed project to be constructed and operated without jeopardizing the Colorado squawfish, humpback chub, and the bonytail chub. That alternative is the release of water from the Dolores Project, or from other projects that regulate flows in the Colorado River, to replace the depletions caused by the Dolores Project. …..The Dolores Project would deplete 131,000 acre-feet of water in an average year. To compensate for

> this loss of water from the river system, it may be necessary that an equal volume be released to the Colorado River from one or more projects. This alternative would prevent the Dolores Project itself from jeopardizing the existence of the fishes of concern…We are intensively studying the endangered Colorado River fishes, but at present we cannot recommend specific flows that should be released. However, our studies may reveal that flow releases totaling less than 131,000 acre-feet annually are adequate for the fishes to survive in the areas and in the numbers that we believe necessary for recovery" (Fish and Wildlife Service 1980).

The original depletion estimate for the Dolores Project, 131,000 af, included downstream releases for the trout fishery. This release is at least 31,097 af and was incorrectly considered a depletion. Thus the present estimated depletion for the Dolores Project is no more than 99,200 af above Lake Powell.

Since the Dallas Creek and Dolores Projects' opinions were written, the Upper Colorado River Recovery Program has been established. Reclamation has also had informal conversations with the Service on how to address the above opinions. The goal of Reclamation and the Service during these discussions was to arrive at a proposed alternative that offsets the impacts of Dallas/Dolores depletions and satisfies the biological opinions on those projects. At the present time the full depletions from the Dallas Creek Project have not been realized; full depletions for Dolores are occurring but, as indicated above, the original depletion estimate was higher (approximately 30,000 af) than what is actually occurring under full depletion.

Upper Gunnison Subordination Agreement—The Fish and Wildlife concurred with a "no effect" determination for impacts to the downstream endangered fish based on two conditions: "1) The 60,000 acre-foot depletion will be consulted on during the upcoming Aspinall Unit consultation; and 2) During the interim, all actions that deplete water out of the 60,000 acre-foot block will be considered new projects and consulted on as we have done in the past." (Fish and Wildlife Service 1999)

Minor water sales—Sixty nine ESA consultations totaling less than 1,000 af of minor water sales have been made from the Aspinall Unit and have received biological opinions, citing the Recovery Program as the reasonable and prudent alternative to avoid jeopardy to the endangered fish due to the depletions. These sales are primarily for augmentation water.

Redlands Canal Fish Screen Biological Opinion—In this opinion (Fish and Wildlife Service 2004), the following conservation measures were included. The opinion identified the Recovery Program as the reasonable and prudent alternative.

> "Reclamation will to the extent allowable under State and Federal law, attempt to release from the Aspinall Unit sufficient water to maintain a

minimum flow of 300 cubic feet per second (cfs) during the months of July August, September, and October in the Gunnison River from the Redlands Diversion to the confluence of the Gunnison River with the Colorado River. Said flows include water necessary to maintain fish access to critical habitat in the Gunnison River below Redlands Diversion for authorized fish and wildlife purposes (providing suitable endangered fish habitat). During periods of drought when the 300 cfs below Redlands cannot be met, Reclamation will work with the Service and water users to attempt to maintain flows lower than 300 cfs below Redlands for endangered fish. The operation will remain in place until the Aspinall Operations Environmental Impact Statement is complete and Reclamation has issued a Record of Decision on Aspinall Operations to address endangered fish flows in the Gunnison and Colorado Rivers. Operations developed through the environmental impact statement and Endangered Species Act Section 7 consultation process will address long term flow requirements below the Redlands Diversion.

15-Mile Reach Programmatic Biological Opinion (Fish and Wildlife Service 1999b)—This biological opinion addressed the continuation of Reclamation operations and depletions in the Upper Colorado River Basin above the confluence with the Gunnison River; Reclamation's portion of 120,000 af/year of new depletions in the same area; and recovery actions in the Colorado River.

Paonia Project Biological Opinion (Fish and Wildlife Service 2002b)—This opinion, related to a temporary water service contract using temporary capacity in the sediment pool of Paonia Reservoir, calls for a portion of the water in the surplus capacity to be released during the spring spill period of the reservoir.

The Service has consulted on approximately 330 water projects/uses in the Gunnison Basin upstream from the Redlands Diversion. These projects included 11,918 af of new depletions and 171,148 af of existing depletions.

3.0 ENVIRONMENTAL BASELINE

3.1 Baseline

For purposes of this PBA, an environmental baseline was developed which includes the past and present impacts of all Federal, State, and private actions and other human activities in the action area; the anticipated impacts of all proposed projects in the action area that have already undergone formal Section 7 consultation under the ESA; and the impact of State or private actions contemporaneous with the consultation process. This baseline is a "snapshot" of species' health at a specified point in time. Under this baseline, the decision to construct the Aspinall Unit for Congressionally authorized purposes and the decisions to build and operate other basin water projects are past federal, state, or private actions, and by definition, they are part of the baseline.

This chapter provides a description of what is in the baseline, a description of baseline aquatic resources and geomorphology, and a description of baseline Aspinall Unit operations.

3.2 River Geomorphology

The Gunnison River is an alluvial, gravel-bed river in reaches important to the endangered fish. In general, changes in the river such as reduced peak flows, bank protection, and other factors which occurred in the 19th and 20th centuries reduced floodplain connectivity and simplified main-channel habitats.

Sediment inflow under pre-development conditions is unknown; however, it may have been considerably less than at present. It is possible that sediment inflows increased markedly around the beginning of the 20th century due to uncontrolled grazing, mining and timber harvesting and initial development of irrigated lands. Under baseline conditions, sediment inflow to the river has not significantly changed since construction of the Aspinall Unit. A large portion of the total sediment load now consists of silt and clay while bed load consists of sand and gravel-sized sediment. Pitlick et al. (1999) concluded that the key factor in maintaining river habitats was to assure that sediment entering critical habitat continues to be carried downstream so it would not accumulate and reduce channel complexity.

Present sediment inflows to the Gunnison River are significant. While spring peak flows have decreased in the river, sediment inflow to the river apparently has not (Pitlick et al. 1999, Pitlick and Cress 2000) because major sediment sources are downstream from the Aspinall Unit. Pitlick et al. (1999) estimated that the annual sediment load carried all the way through the Gunnison River dropped by more than 40% from 1964 to 1978—the net effect of this would be accumulation of sediment in the river channel causing a loss of channel complexity. Pitlick also noted that between 1979 and 1993 the annual sediment load of the river returned to pre-1964 conditions. Pitlick found that a given incremental increase in flow has a much greater effect on sediment movement at higher flows than at lower flows based on his work on the Colorado River.

Because the Gunnison River has a gravel bed and large-scale changes in the geomorphology of rivers generally come about only as a result of significant bed load transport, large floods are needed to create significant areas of new habitat. More moderate flows can maintain habitats, however.

Geomorphologists identify two important phases in sediment transport: initial motion and significant motion. Initial motion is the level that begins to remove fine sediments from the channel, including the interstitial spaces. Significant motion is characterized by continuous movement of most particles in the channel. Pitlick and Cress (2000) found that in the Gunnison River initial motion occurs at approximately half bankfull discharge and significant motion occurs at approximately bankfull discharge. “Flows equal to or greater than half bankfull are needed to mobilize gravel and cobble particles on a widespread basis, and to prevent fine sediment from accumulating. …Bankfull flows are

sufficient to fully mobilize the bed material and thereby maintain the existing bankfull hydraulic geometry (Pitlick et al. 1999)."

In addition to the magnitude of flows, the duration of the flow is important in sediment transport. Based on field observations, Pitlick et al. (1999) recommended that to maintain habitat conditions, half bankfull and bankfull flows should occur with a long-term average equal to what occurred during 1978-1997. To improve habitat conditions the two threshold flows should occur with a long-term average equal to what occurred during 1993-1997. Required duration may best be determined through long-term monitoring.

Median values for initial and significant motion in various reaches of the Gunnison River between Delta and the Redlands Diversion were calculated to be 8,070 cfs and 14,350 cfs based on 54 cross sections. Initial motion begins at one site at 4,660 cfs and occurred at all 54 sites at 12,700 cfs. Bankfull motion begins at one site at 7,352 cfs but is not reached in the entire river until flows exceed 28,719 cfs (Pitlick et al. 1999). Table 6 provides information on the percentage of river cross sections that reach initial and bankfull motion at various river flows. Attachment 4 provides more detailed information on flow levels needed to reach half and bankfull levels at all 54 cross sections.

Based on Pitlick et al.'s (1999) work and using gage data available between 1897 and 1965, the frequency of years where half bankfull flows occurred dropped from 76 % pre-Aspinall Unit to 44 % post-Aspinall Unit. Frequency of bankfull years dropped from 45 % to 6 %. In addition the average number of days per year that flows of 8,070 occurred dropped from 26.6 to 14.5; the range changed from 0-71 to 0-74 days. For flows of 14,350 cfs or more, average number of days per year dropped from 6.5 to 2.5 and the range changed from 0-35 to 0-29 days.

Milhous (1998) conducted an intensive river morphology study on a 1-mile reach of the Gunnison River near RM 38. Twenty cross sections were established in the 1-mile reach. Based on measurements over a 3-year period several sediment transport levels were estimated:

- Flush fine sediments from the surface of the bed – 12,535 cfs
- Remove gravel from pools – 17,000 cfs
- Scour side channels – 7,415 cfs
- Prevent fine sediments from being deposited on riffles where spawning would occur – 950 cfs.

Table 6. Gunnison River: percentage of cross sections reaching initial motion and bankfull thresholds at various flows in critical habitat reach.

Flow (cfs)	Percentage of cross sections reaching thresholds	
	Initial Motion (half bankfull)	Significant Motion (bankfull)
5,000	7	0
6,000	19	0
7,000	33	0
8,000	46	2
8,070	50	2
9,000	69	4
10,000	81	6
11,000	81	13
12,000	94	26
13,000	100	28
14,000	100	46
14,350	100	50
15,000	100	61
16,000	100	67
20,000	100	81

Differences between the Milhous and Pitlick studies result from large bed material in Milhous's study reach. The flow level Milhous determined for preventing fine sediments from being deposited in riffle areas is important during spawning periods to prevent fines from smothering embryos or eggs that might be deposited in the gravels.

Pitlick (1999) also estimated initial motion and bankfull flows for a Colorado River reach downstream from the Gunnison River represented by the Colorado-Utah stateline gage. Initial motion was estimated at 18,538 cfs and bankfull flow at 34,957 cfs. The frequency of years that initial motion was reached decreased from 71 % to 61 % between the pre- and post-Aspinall periods. The frequency of years that bankfull flow was reached decreased from 29 % to 21 %. These changes would reflect water developments in the upper Colorado River in addition to Aspinall Unit operations.

3.3 Past Water Uses and Reservoir and River Operations

Early water uses in the Gunnison Basin were for mining and irrigation. By 1900, most of the readily available sources of irrigation water had been developed by private individuals and small irrigation companies (Colorado Water Conservation Board 1962). Prior to the 1960's, Taylor Park Reservoir was the largest regulating reservoir in the basin, although there were numerous smaller reservoirs on Grand Mesa and elsewhere. By 1960, agricultural water depletions in the basin were estimated at 312,000 af (Colorado Water Conservation Board 1962) and there were additional depletions from domestic uses and reservoir evaporation.

In the 1960-1990 period, several moderately sized reservoirs (Table 1) were constructed in the basin including Ridgway, Paonia, Crawford, and Silver Jack.

The Aspinall Unit was constructed in the 1960-1980 period. Primary water storage at the Aspinall Unit occurs in the uppermost and largest reservoir, Blue Mesa. Water can be released from the reservoirs through the powerplants and/or river outlets (bypasses). As designed, spillway use is limited to periods when the reservoirs have reached high contents. Spillway use at Blue Mesa and Morrow Point is very infrequent. Due to the relatively small powerplant/bypass capacity at Crystal Dam, spills occur more frequently. In general, operation of the Aspinall Unit has changed the natural river flow pattern by storing spring peak flows and increasing flows during the remainder of the year. The effect of these past operations is included in the environmental baseline.

Table 7 summarizes statistics on the Aspinall Unit facilities.

Table 7. Aspinall Unit statistics.

Capacities (acre-feet)	Blue Mesa	Morrow Point	Crystal
Dead storage	111,200	165	7,700
Inactive storage	81,070	74,905	4,650
Active storage	748,430	42,120	12,890
Live storage*	829,500	117,025	17,540
Total storage	940,700	117,190	25,240
Outlet capacities (cfs)			
Powerplants (max)	2,600-3,400	5,000	2,150
Powerplant bypass	4,000-5,100	1,400-1,600	1,900-2,200
Combined powerplant and bypass(max)	6,100	6,500	4,350
Spillway	34,000	41,000	41,350

*-Live storage is the combination of the active and inactive storage. It represents storage that physically can be released from the reservoir.

-Blue Mesa Reservoir shares one penstock for both river outlet and powerplant releases; the combined releases of these two are constrained to about 6,100 cfs.

-The hydraulic capacities shown in the table assume full reservoir conditions. At lower elevations, the hydraulic capacity would be less. Also system efficiencies may affect the hydraulic capacity.

-Full capacity may not always be available due to scheduled maintenance, equipment malfunction, or power system reserve requirements.

-There are no specific recreation or fishery pools in the reservoirs.

Reclamation manages water at the Aspinall Unit within certain sideboards that include annual snowpack conditions, downstream senior water rights, minimum downstream flow requirements, powerplant and outlet capacities, reservoir elevation goals, fishery management recommendations, dam safety considerations, and others. Certain sideboards are non-discretionary such as honoring senior water rights and flood control, while others such as reservoir elevation criteria to reduce landslides are given a high priority

To conserve water for later use and to provide drought protection, an operational goal is to fill Blue Mesa. Full reservoir is 7,519.4 feet; however, operations are designed to

reach around 7,517 feet (or less, dependent on forecast) which provides a safety factor for controlling the reservoir in case of sudden high inflow events due to heavy rains or high rate of snowmelt. Another operational goal is to draw Blue Mesa down to an elevation of 7,490 by December 31st to reduce the chance of ice jams and associated flooding upstream.

The five generators at the three dams of the Aspinall Unit are capable of generating up to 283 megawatts of electricity. Morrow Point has the largest capacity—its generators produce more than twice as much electricity as those at Blue Mesa. The Western Area Power Administration (Western) markets electricity generated by the Aspinall Unit in conjunction with power from Glen Canyon and Flaming Gorge Dams and other plants of the Colorado River Storage Project as part of an integrated system that provides electricity to all states of the Colorado River Basin. The upstream powerplants of the Aspinall Unit (Blue Mesa and Morrow Point) are critical in that they are operated to provide load following and peaking power. Crystal Reservoir then is committed as a regulation reservoir to stabilize releases to the Gunnison River. Peaking operations at Blue Mesa and Morrow Point help meet demands for electricity that change on an hourly, daily, and weekly basis.

The environmental baseline includes Aspinall Unit operational conditions before efforts were made to “bundle” surplus or risk of spill water into spring peaks for endangered fish. Spills and bypasses occur under the baseline; however, there is no effort to manage this water for specific endangered species needs. To the extent possible, water forecasted to be spilled or bypassed is released early in the year through the powerplants. Essentially, under the environmental baseline the Aspinall Unit is operated to maximize water storage and hydropower production, and minimize flow variations in the Gunnison River downstream from Crystal Dam.

Baseline hydrology conditions are discussed in Section 3.4 of the assessment while baseline conditions of listed species are presented in Section 4.0. Under the baseline:

- Existing spring flood control operations are continued (using discretion and being proactive to maintain flows below 14,000 cfs or normally considerably less at Delta [Delta City area above the Uncompahgre confluence]). Flood control operations would continue to be coordinated with the city and county of Delta. The Corps of Engineers flood control manual requires that efforts are made to keep flows below 15,000 cfs.

- Blue Mesa winter icing elevation target--7490 feet at end of December—is met to reduce chances of ice jams causing upstream flooding in the Gunnison area, for example in the Dos Rios subdivision area.

- Peaking power operations conducted at Morrow Point and Blue Mesa continue with flows downstream from Crystal regulated through uniform releases to offset impacts of peaking operations upstream. Blue Mesa releases range from 0 to 3,400 cfs and Morrow Point releases from 0 to

5,000 cfs. During Crystal spills, variations in Morrow Point peaking releases are reduced to avoid large daily fluctuations downstream from Crystal.

- Operations continue to meet 300 cfs downstream from the Gunnison Tunnel except in certain cases of significant drought (as determined by reservoir elevation projections) and during Aspinall Unit emergencies when flows may be reduced to 200 cfs as measured at the USGS Gage below the Gunnison Tunnel. Such a decision would be made only after coordinating with the State of Colorado and other interested parties.

- Morrow Point and Crystal Reservoirs' daily fluctuations are limited by landslide criteria.

- Existing contracts and agreements are honored; these documents include provisions for operations in extreme conditions of drought and flooding. There is discretion for operations during emergencies, regular maintenance activities, and extraordinary maintenance.

- Existing water and power contracts from the Aspinall Unit are part of the baseline (note that CRSP power contracts are not "unit specific" but apply to integrated project facilities). Water contracts have flexibility under water shortage conditions.

- The baseline continues to meet power system requirements of the North American Electrical Reliability Council and the Western Electricity Coordinating Council such as generation control, voltage regulation, black start capability, and reserves. For example, Aspinall Unit operations--such as Morrow Point peaking--can be used in emergency situations to prevent major power problems in the West.

- Consistent with authorized purposes, the Aspinall Unit is operated subject to water laws and water rights as decreed under Colorado water law and the Law of the River.

- Existing depletions in the Gunnison River Basin from the exercise of private and public water rights under Colorado law (including evaporation, diversions, transpiration, etc) continue as part of the baseline.

- The estimated portion of the 60,000 af subordination (Aspinall rights subordinated to water uses in the Gunnison Basin upstream from Crystal Dam) being used at this time (8,600 af in place now).

- For purposes of the environmental baseline, it is assumed that projected water uses with completed ESA and NEPA compliance are occurring. This would include full Dallas Creek Project depletions (and Dolores

Project depletions which are now fully developed from the Dolores River) and also include existing contracts with the Upper Gunnison Water Conservancy District and with private and public water users for Blue Mesa water.

- The baseline recognizes that one of the purposes of the Aspinall Unit is "…storing water for beneficial consumptive use, making it possible for the States of the Upper Basin to utilize, consistently with the provisions of the Colorado River Compact, the apportionments made to and among them in the Colorado River Compact and the Upper Colorado River Compact, respectively…".

  This use is compatible with the Recovery Program which has a goal of fish recovery and water development. Under the proposed action, "remaining project yield" (not precisely known, but approximately 300,000 af minus subordination water use and existing water contracts) will continue to be stored or go downstream on an interim basis and be modeled as such. It will be recognized that this remaining water may very well be developed in the future, upstream or downstream from the Unit, pursuant to the Colorado River and Upper Colorado River Basin Compacts, and subject to and consistent with the Unit's authorized purposes and other applicable laws. The State of Colorado has identified significant needs through the State Water Supply Initiative process and has significant consumptive use depletions remaining for use under the Colorado River Compact of 1922 and the Upper Colorado River Basin Compact and a portion of this would legally be available for development using sources in the Gunnison Basin. The unused portion of the Unit yield would not be relied on as part of any permanent solution that seeks to provide releases for flow recommendations or any subsequent modifications to them.

  The potential use of remaining Unit yield is not modeled because specific foreseeable proposals are not available. Alternative would recognize that consumptive use up to a total of 300,000 af of project yield may be used in the future under Colorado's compact entitlements and its use would not be precluded by the proposed action. When future water sales or uses of portions of the "remaining project yield: from the Unit are proposed, the proposals will be evaluated under NEPA.

  If Reclamation determines the proposed sale or use may adversely affect a listed species, ESA consultation will commence. If the Recovery Program has made sufficient progress implementing the Recovery Action Plan, then implementation of the Recovery Program may serve as reasonable and prudent measures or reasonable and prudent alternatives, as appropriate. The Section 7 consultation, sufficient progress, and historic projects agreement for the Upper Colorado River Basin Recovery Implementation

Program, as revised in 2000, provides information on ESA compliance for future projects, such as use of Aspinall Unit yield.

- The baseline includes Taylor Park 1975 and 1991 Agreements and the Taylor Park refill right in place. Up to approximately 100,000 af of Taylor Park water may be stored in Blue Mesa at any given time. Aspinall Unit is operated to protect Uncompahgre Project water stored in Blue Mesa under the Taylor Park Exchange Agreement. The Uncompahgre Project's Gunnison Tunnel and Dallas Creek Project's Ridgway Reservoir exchange continue in place.

- As a general guide, individual flow changes downstream from Crystal are planned to be the greater of 500 cfs or 15 % of flow when ramping up and the greater of 400 cfs or 15 % of flow when ramping down. Higher rates may be used to react to special circumstances, for example for flood control and emergencies or when canyon flows exceed 2,000 cfs.

- Gunnison Gorge flow decreases that could damage brown trout redds after October 15th are avoided when practical. Flow decreases or rapid flow changes are avoided after April 15th for rainbow trout spawning when practical.

3.4 Hydrology and Water Quality

3.4.1 Modeling

The baseline and the proposed changes in storage and release from the Aspinall Unit were modeled. The scope of the model encompasses the Gunnison River Basin from Blue Mesa Reservoir to the confluence with the Colorado River. RiverWare, a software modeling tool developed by CADSWES (University of Colorado) for the Bureau of Reclamation and the Tennessee Valley Authority for operations and planning studies of river basins and river systems, was used. The daily planning model, developed for initial analysis in 2002-2003 was updated in 2007. Various operations of the Aspinall Unit were modeled. The modeling period originally utilized a single 26-year trace from January 1975 through December 2000. The modeling period for this new analysis has been extended through December 2005 and now consists of a single 31-year trace. The model is used as a comparison and planning tool. The proposed action was modeled to determine river flows for the 1975-2005 study period and these flows were compared to modeled baseline flows. Results of modeling estimate conditions as if the baseline or proposed action were in place during the 1975-2005 period. Results are a general prediction of future conditions under the baseline or proposed action; however, actual future hydrology conditions will depend largely on future weather conditions. Additional information on modeling is found in Attachment 12.

3.4.2 River Flows

Table 8 presents modeled baseline peak flows and average monthly flows for the period of study at the Whitewater gage assuming the Aspinall Unit and other water projects in place and operating.

Table 8. Baseline river flows (average monthly cfs), Gunnison River at Whitewater, for period of record used in Biological Assessment analysis assuming Aspinall Unit and other water projects and uses in place and operating.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Peak daily mean for Year
1975	766	751	1326	3`93	6385	5467	3589	1937	2082	1993	1683	1650	8927
1976	1226	1286	1121	1678	3429	2484	1721	1120	1524	1628	1122	858	5130
1977	880	771	812	768	846	761	795	750	774	883	868	753	1581
1978	745	676	841	3581	6361	5805	2426	1319	1370	844	972	1149	10678
1979	1767	2711	2746	4571	9213	6919	2879	1680	1739	1635	1511	1412	15164
1980	1214	2580	1955	4225	9887	7174	2330	1305	1291	1007	1337	1518	13884
1981	1064	600	887	1337	1542	1393	1021	923	1181	1455	1083	823	3773
1982	1279	1388	1310	3463	6959	4748	2475	2077	2787	2731	2502	2443	9140
1983	1436	1360	1865	2839	8631	13662	7850	3138	2207	2477	2284	2582	20640
1984	2848	2630	2703	4968	13738	13722	6757	2894	2525	2998	2955	3180	20782
1985	2835	2360	2021	6747	10494	10121	3312	1567	2319	2723	2557	2655	15186
1986	2519	1744	3803	5796	8378	6447	5018	1995	2747	3378	3236	3305	10357
1987	2073	1885	2035	5198	6706	5877	2023	2088	2369	1851	1575	1569	9241
1988	1145	1301	1168	2309	2206	1901	1509	963	1351	1148	937	867	3436
1989	1027	1278	1790	2566	1805	1594	1442	1110	1258	1148	970	892	2465
1990	778	725	792	1007	1643	1662	1363	908	1156	1353	1163	1194	2574
1991	988	919	1042	1854	4985	4124	1937	1680	2073	1942	1702	1813	8412
1992	1135	956	1175	3314	3712	2731	2088	1702	1784	1961	1716	1396	6063
1993	1083	1325	2857	4991	12960	9242	3771	2220	2374	2650	2244	1969	20492
1994	1344	1230	1505	2167	3534	2830	1568	1251	1562	1771	1579	1518	4919
1995	1143	1056	2700	3797	8893	13680	12698	3043	2695	2780	2832	2762	19346
1996	1674	2286	2858	4046	5822	3341	1903	1541	2065	1956	1982	2079	7860
1997	2706	2739	2972	4431	8647	8757	3408	2517	3232	3188	2824	2730	11996
1998	1582	1469	2141	3646	7196	3200	2295	1545	1890	2049	1841	1732	9877
1999	1178	1159	1461	1383	3276	4499	2851	2882	2751	2468	2229	2188	6793
2000	1456	1464	1609	2764	2729	1831	1661	1141	1440	1623	1246	1133	4817
2001	1073	924	1176	1520	2939	2184	1817	1545	1841	1689	1403	1358	3487
2002	1069	911	904	1095	918	731	708	835	1097	1154	883	749	1153
2003	705	699	787	1169	2998	1809	629	767	1233	1020	859	753	5312
2004	754	730	1117	2039	2409	1543	1385	936	1325	1306	981	887	3413
2005	1206	1734	1578	4324	8022	4545	2184	1478	1686	1949	1528	1221	13574
Avg	1377	1408	1711	3122	5718	4993	2820	1641	1862	1895	1697	1650	

Development of water resources in the Gunnison Basin began in the late 19th Century, primarily for irrigation. Storage reservoirs were generally small and spring peak flows, while reduced, remained high. The extensive irrigation diversions significantly reduced

summer and fall base flows and probably increased summer water temperatures and concentrations of pollutants.

Construction of storage reservoirs, including the Aspinall Unit, increased significantly in the second-half of the 20th century and greatly reduced spring peak flows while tending to increase base flows from early to mid-20th century levels (Figure 5 in Section 4.3). Tyus and Saunders (2001) concluded that the Aspinall Unit resulted in extreme alteration of historic flows in the Gunnison River.

The Aspinall Unit has not significantly changed the annual volume of water flowing downstream but has changed the flow pattern. The Aspinall Unit's operation has tended to increase flows from August through March or April and to reduce flows in May through July. Extreme low flows in the lower Gunnison have largely been eliminated. Prior to operation of the Aspinall Unit, average monthly flows at Whitewater were often below 900 cfs and occasionally below 200.

3.4.3 Water Quality

Butler (2000) summarized water quality data for the Gunnison River in critical habitat under baseline conditions. Three parameters were reported to exceed State water-quality standards (for which 85th percentile concentrations exceeded numeric standards) for the Gunnison River-sulfate, total iron, and selenium. Other constituents occasionally exceed standards but the 85th percentiles were less than the standards. Water released from the Aspinall Unit is of very high quality and tends to dilute inflows of pollutants from tributaries such as the North Fork and Uncompahgre rivers. Overall, operations of the Aspinall Unit have improved chemical water quality conditions in the critical habitat of endangered fish. Attachment 5 contains detailed water quality data collected by the U.S. Geological Survey at the Whitewater gage and in the Colorado River in critical habitat.

Of the elements that exceed state standards, selenium is of concern to fish and wildlife resources. Potential biological effects of selenium concentrations are discussed in Section 4.3. It is estimated that deep percolation and seepage of water from irrigation and irrigation systems contribute about 90 % of the groundwater that mobilizes selenium in the basin (Reclamation 2006). It is estimated that 60 % or more of the selenium loading measured at the Whitewater gage originates from an area encompassing the Uncompahgre River basin and the service area of the Uncompahgre Irrigation Project; the remainder from private water uses, other federal projects and natural inputs. Loading is highest from newly irrigated lands and gradually subsides. Selenium loading to the Gunnison River primarily results from canal/lateral seepage and deep percolation from irrigated fields, lawns, and ponds. Runoff from desert lands with Mancos shale derived soils is another source. The majority of the loading to the Gunnison River occurs on the east side of the Uncompahgre Valley and the majority of the loading to the Colorado River occurs in the Grand Valley. Hamilton (1999) reported that selenium concentrations in the early part of the 20th century were significantly higher in major rivers and tributaries than at present and hypothesized that these extreme concentrations may have played a significant role in the decline of the fish. Concentrations in the Gunnison River

as high as 80 ppb were reported during this period (NIWQP display based on Hamilton 1999).

Attachment 6 includes graphs of dissolved selenium concentrations from 132 samples taken at various flows between 1976 and 1998 at the Whitewater Gage. The graph shows a general inverse correlation between flow rate and selenium concentration. However, the corresponding selenium concentration varied widely at flows under 4,000 cfs. For instance, the maximum recorded selenium concentrations corresponding to flows greater than 4,000 cfs was 3 ppb while at flows between 2,000 and 3,000 cfs concentrations varied from 1 to 10 ppb. The median value for these samples was 5 ppb; the Colorado chronic water quality standard for selenium is 4.6 ppb. Attachment 6 also contains tables of average monthly, average annual, maximum annual and minimum annual selenium concentrations through the study period for baseline and the proposed action.

Concentrations of selenium in the lower Gunnison River and elsewhere in the Colorado River Basin may be a concern for endangered fish. During informal consultation, the Service has requested that selenium issues be addressed in this PBA.

Beginning in the late 1980's, Reclamation, the Service, the U.S. Geological Survey and others participated in the National Irrigation Water Quality Program (NIWQP) to identify selenium sources and problems and to implement solutions. The NIWQP determined that "Selenium concentrations in the lower Gunnison River are at levels that adversely affect reproduction in selenium sensitive species including some aquatic birds and endangered fish." The Service (1994) recommended *in situ* studies to help determine whether trace elements such as selenium are limiting razorback survival in the Gunnison. Concerns were also noted in certain backwaters of the Green and mainstem Colorado River and in the Colorado downstream from the Gunnison confluence. Further, in a December 1998 memo, Region 6 of the Service stated the "The Service believes that the remediation of selenium impacts is one of several factors that needs to be addressed as part of the overall effort to recover the Colorado River endangered fishes."

In August 2002 the Service published Recovery Goals for the razorback sucker and Colorado pikeminnow which include:

> "Selenium is hypothesized as contributing to the decline of the endangered fishes of the Colorado River Basin (U.S. Fish and Wildlife memorandum, December 22, 1998). It is a water quality factor that may inhibit recovery by adversely affecting reproduction and recruitment (Stephens et al. 1992; Hamilton and Waddell 1994; Hamilton et al. 1996; Stephens and Waddell 1998; Osmundson et al. 2000a). Selenium concentrations in certain areas of the basin (e.g., Green River near Jensen, Utah; Gunnison River downstream from the Uncompahgre River confluence; and upper Colorado River downstream from Palisade, Colorado) exceed those shown to impact fish and wildlife elsewhere, and, although results are inconclusive as to exposure thresholds that cause specific effects, some studies suggest deleterious effects on razorback

> sucker and Colorado pikeminnow. The National Irrigation Water Quality Program is addressing selenium issues in the upper basin by implementing remediation projects to reduce selenium levels in areas of critical habitat. The adverse effects of selenium contamination on razorback sucker reproduction and survival will be reevaluated before downlisting and necessary protection will be implemented before delisting."

In 1998, the NIWQP began actions to mitigate selenium impacts both in the lower Gunnison River basin and in the Grand Valley in the vicinity of Grand Junction. However, funding for the NIWQP was suspended in 2004.

In 1997, the Colorado Water Quality Control Commission (Commission) lowered the state selenium standard for aquatic life to 4.6 ppb in the lower Gunnison River to be consistent with the EPA national standards. The Commission also requested that a group of local, state, and federal agencies organize and work to specifically reduce selenium loading.

As a result, the Gunnison Basin Selenium Task Force (Task Force) was formed in 1998 to address exceedance of the State's water quality standard for selenium in four stream segments including the lower Gunnison River. The Task Force is "a group of private, local, state and Federal interests committed to finding ways to reduce selenium in the affected reaches while maintaining the economic viability and lifestyle of the lower Gunnison River basin." Task Force members include City of Delta, City of Montrose, Colorado Department of Health and Environment, Colorado Division of Water Resources, Colorado Division of Wildlife, Colorado River Water Conservation District, Colorado Soil Conservation Board, Colorado State University Cooperative Extension, commercial farmers, ranchers, and dairymen, Delta County Commissioners, Delta County Health Department, Delta Soil Conservation District, High Country Citizens Alliance / Sierra Club, Montrose County Commissioners, Natural Resources Conservation Service, Shavano Soil Conservation District, Towns of Hotchkiss and Paonia, Uncompahgre Valley Water Users Association, Reclamation, the Service, the U.S. Geological Survey and others. The Task Force staff has recently been funded by the Colorado River Water Conservation District and Reclamation. Additional funding in earlier years was acquired through grant programs.

In addition to specific selenium reduction activities, extensive salinity-control activities have been underway in the lower Gunnison River basin as well as along the mainstem Colorado in the Grand Valley and in the Green River basin. These activities also contribute to the reduction of selenium loading.

Significant salinity control efforts began first in the Grand Valley where 246 miles of canals and laterals have been lined or placed in pipe and 34,565 acres have been treated with on-farm measures. Although targeted at salinity reduction, these projects also reduce selenium loading. In addition, backwater areas at the Orchard Mesa and Colorado River Wildlife Areas have been treated under NIWQP to reduce selenium concentrations in areas used by endangered fish and these efforts have been partially successful.

The first improvements in the Lower Gunnison area occurred under the Natural Resources Conservation Service's salinity control programs and later under the EQIP. Work generally involved on-farm irrigation efficiency improvements aimed at reducing deep percolation and salt loading. The EQIP remains active in the lower Gunnison basin. The major practices being installed are underground pipelines, ditch lining, land leveling, irrigation water control structures, sprinkler systems, gated pipe, and surge irrigation systems**.** Approximately $54 million has been expended to reduce salinity loading by 88,000 tons per year through fiscal year 2007. Unquantified reductions in selenium loading have also very likely occurred due to this work.

During the early 1990's, Reclamation implemented a project to replace the use of Uncompahgre Project canals and laterals carrying winter livestock water with a system of piped domestic water delivery facilities; and this reduced seepage throughout the Uncompahgre Valley. This program had a total cost of $24 million and reduced the loading of an estimated 41,000 tons of salt annually and an unquantified amount of selenium.

Beginning in 1998, targeted selenium control projects in the lower Gunnison River Basin have been developed through the efforts of the Reclamation-funded NIWQP, the Gunnison River Basin Selenium Task Force, and Uncompahgre Valley Water Users Association (UVWUA). Successful applications have been awarded project funding by the CRBSCP. This funding has been supplemented by NIWQP funding and in-kind services from the UVWUA. An initial lateral piping project was constructed south of Montrose in the Montrose Arroyo drainage (Phase I, East Side Laterals Project). The USGS reported significant selenium and salinity load reductions as a result of this project. Based on the success of that project, additional projects (Phases 2 and 3) have been funded by the CRBSCP, supplemented by Congressional "write-ins" for selenium control and continued in-kind services from UVWUA. These projects involve the piping of unlined irrigation laterals on the east side of the Uncompahgre Valley, the highest selenium loading area in the lower Gunnison River Basin. Approximately 51 miles of irrigation laterals on the east side of the Uncompahgre Valley have been placed in pipe, or are presently funded for piping, to reduce salt and selenium loading. This effort is summarized in Table 9.

Figure 2 indicates a general reduction in selenium concentrations in recent years, probably as a result of activities discussed above. The increase in concentrations in the 2002-2004 period results from the extreme drought and low water conditions in that timeframe.

Table 9. Status of East Side Uncompahgre Valley Laterals Project*.

Phase	Original length of piped laterals (miles)	Salt reduction (tons/yr)	Salinity Program Funding ($)	Selenium Funding ($)	Total Funding(1) ($)
1	8.5	2,300	695,366	550,809	1,246,175
2	20.5	6,100	2,133,000		2,133,000
				1,706,000	1,706,000
3	10.5	2,300	1,262,561		1,262,561
4	11.4	3,651	2,002,285	800,000	2,802,285
total	50.9	14,351	$6,093,212	$3,056,809	$9,150,021

*Total Funding does not include resources and in-kind services contributed by the Uncompahgre Valley Water Users Association.

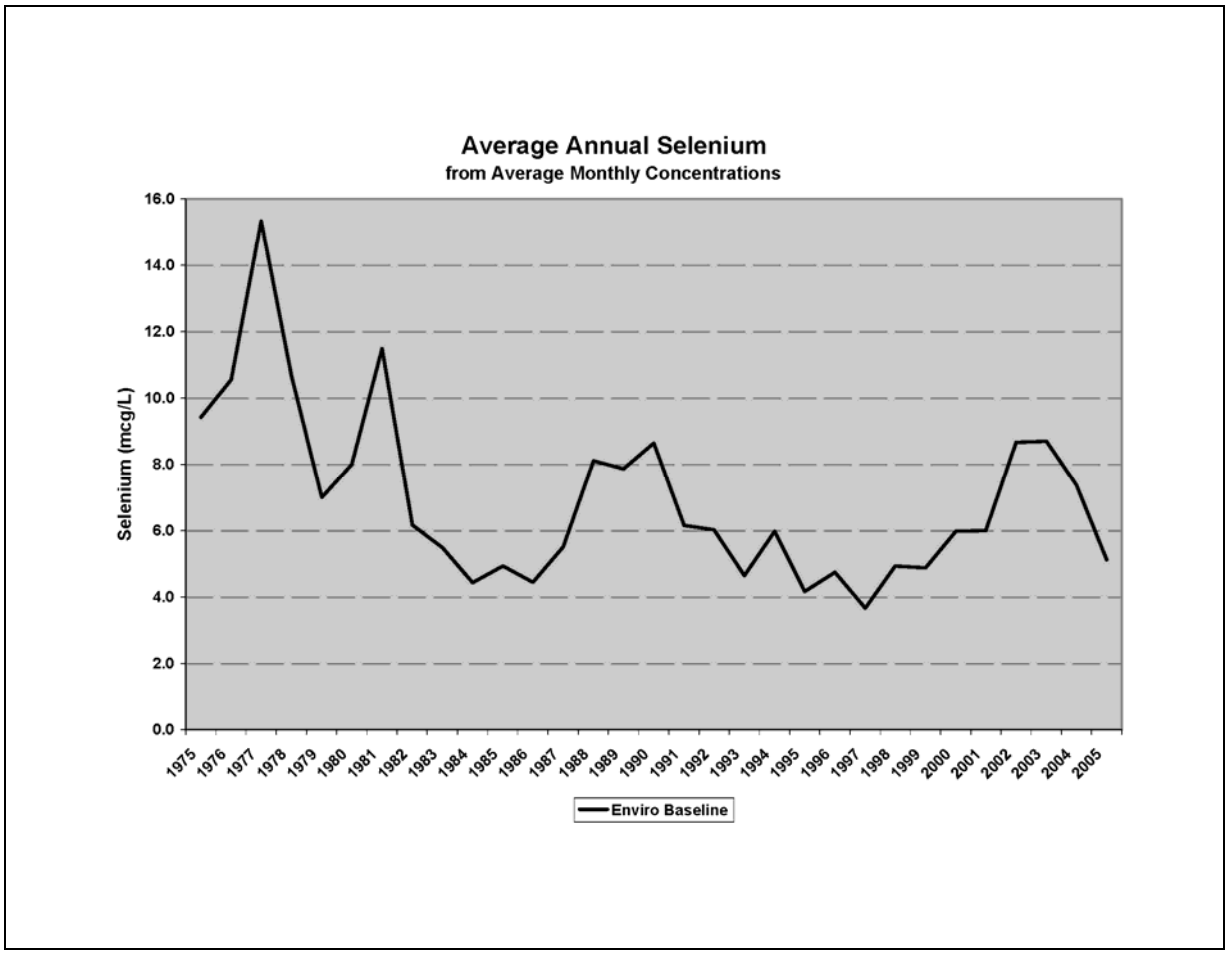


Fig 2. Baseline average annual selenium concentrations, Gunnison River at Whitewater gage.

In 2006, Reclamation in conjunction with the Task Force produced an appraisal-level report evaluating selenium remediation concepts for the lower Gunnison River Basin (Bureau of Reclamation 2006a). The purpose of the report was to determine the

reasonableness of attaining certain water quality goals. The report identified two remediation alternatives.

Alternative 1: Water Quality Standard Attainment Plan to meet State water quality standard
Alternative 2: Endangered Species Protection Plan to meet the NIWQP goal for food organisms

Based on 1997-2001 streamflow levels, the following selenium reduction amounts were estimated for these two alternatives:

Alternative 1: Meet selenium water quality standards (85th percentile value of 4.6 ppb)

Meet standard at:	Load reduction needed
Uncompahgre River at Delta	5,630 pounds/year
Gunnison River at Whitewater	5,000 pounds/year

Notes: 1) these values are not additive; if 5,630 lbs/year is reduced in the Uncompahgre, the standard is met at Whitewater; 2) the period of record for this computation was 1997-2001; using a different period will likely change the required load reduction.

Alternative 2: Meet the NIWQP goal of 3 ppm in food organisms

Meet goal at:	Load reduction needed
Gunnison River at Whitewater	~ 13,000 pounds/year

Notes: 1) The 5-year average selenium load is about 7,600 pounds/year for the Uncompahgre River at Delta and 19,400 lbs. /year for Gunnison River at Whitewater.

The projected load reductions needed to meet the State Standard (Alternative 1) were based on detailed USGS studies and have a reasonable level of certainty. In the case of Alternative 2, the estimate of selenium reduction needed to meet 3 parts per million (ppm) is of much lower certainty, being based only on rough approximations developed by the NIWQP. Reclamation considers the selenium load reduction needed to meet the 3 ppm goal in food organisms to be unknown.

The 2006 report suggested that Alternative 1 - meeting the state water quality standard for selenium in the lower Gunnison and Uncompahgre Rivers - was technically attainable based on the selenium reduction needed for the 1997 to 2001 period of record. Alternative 1 includes piping 127 miles of laterals and lining 19 miles of canals on the east side of the Uncompahgre Valley along with significant on-farm and other improvements. Based on the 2006 report, it was projected that if all these improvements are implemented, selenium loads would be reduced by 4,300 to 6,100 pounds/year.

The quantification of the selenium reduction needed to meet the state standard in the lower Gunnison River is dependent on the hydrologic period of record selected. A 2008 study completed by the USGS (for use in developing the State's TMDL) uses a 2001-2005 period and documents the need to reduce the load by about 8,600 pounds per year to achieve the standard during that time period.

The availability of funding is the primary limiting factor in implementing selenium and salinity reduction plans. Additionally, the continuing implementation of beneficial salinity control projects is dependent on the competitive selection of such projects by the CRBSCP and supplementary funding provided via Congressional "write-ins" garnered by the UVWUA and others. The continuation of both the CRBSCP and EQIP are dependent on Congressional funding.

It should also be noted that urban/suburban growth and land-use changes are believed to significantly affect both selenium and salt loading in the area. Some trends appear to be downward, but growth that occurs on lands that were not previously irrigated (and leached) and new aesthetic or recreational ponds may be countering the trends. Studies are currently underway by the US Geological Survey to evaluate land use changes and effects on salinity and selenium loading. These studies are being funded through the CRBSCP.

Another water quality consideration, water temperature, can affect the life cycles of the fish. Early irrigation diversions and return flows probably tended to increase water temperatures in the Gunnison River and its major tributaries year-round. Later construction and operation of the Aspinall Unit has tended to lower downstream temperatures in the summer and raise them in the winter, due to hypolimnion releases from the reservoirs. Stanford and Ward (1983) reported that the river immediately downstream from the Aspinall Unit was several degrees warmer in the winter and 7-10 degrees C cooler in the summer. Before reservoir regulation, annual degree days increased from 2,895 to 4,132 between the East Portal and Whitewater; and after regulation increased from 1,361 to 3,432.

Table 10 presents recent temperature data from the Gunnison River collected under the Recovery Program. There is a general inverse correlation between flow and water temperature at Delta and Whitewater with higher releases resulting in lower water temperatures (for example, see 1993, 1995, and 1997 in Table 10), although this is not always true as other variables such as tributary flow and weather affect the temperatures also. Additional water temperature data and the relationship between temperatures at Crystal Dam and the Whitewater gage are found in Attachment 6. Spring and summer water temperatures in areas such as backwaters would be expected to be higher than in main channel areas.

3.4.4 Climate Change

In determining what future effects are reasonably certain to occur, Reclamation must determine the difference between future effects that are speculative, and effects that are likely to occur under the environmental baseline as compared to the proposed actions. The hydrologic and water quality models included variability designed to reflect conditions likely to occur over the 25 year time frame for this consultation. However, future climatic conditions could be warmer, wetter, cooler, or drier than the modeled conditions.

Table 10. Mean summer water temperature (degrees C) of the Gunnison River at the Delta and Whitewater gages, 1992-2000 (from McAda 2003).*

Year/Month/Mean Flow at Whitewater+	Gunnison River at Delta	Gunnison River at Whitewater	Year/Month/Mean Flow at Whitewater+	Gunnison River at Delta	Gunnison River at Whitewater
1992			1997		
Jun 2,819 cfs	16.1	17.9	Jun 8,184 cfs	13.2	12.6
Jul 1,806 cfs	17.6	20.3	Jul 3,595 cfs	16.2	18.1
Aug 1,716 cfs	17.5	20.6	Aug 2,474 cfs	17.7	19.7
Sep 1,570 cfs	15.4	17.9	Sep 3,257 cfs	15.8	17.1
1993			1998		
Jun 9,054 cfs		13.2	Jun 3,273 cfs	14.3	16.2
Jul 3,279 cfs		18.1	Jul 1,913 cfs	19.0	21.7
Aug 2,157 cfs		19.3	Aug 1,472 cfs	18.0	
Sep 2,377 cfs		16.1	Sep 1,879 cfs	15.7	
1994			1999		
Jun 2,567 cfs		19.0	Jun 3,549 cfs	15.0	
Jul 1,263 cfs		21.7	Jul 2,423 cfs	18.4	
Aug 1,276 cfs		21.8	Aug 3,418 cfs	16.5	
Sep 1,701 cfs		17.1	Sep 3,172 cfs	14.6	
1995			2000		
Jun 13,050 cfs	11.4	12.0	Jun 1,941 cfs	16.5	19.5
Jul 11,950 cfs	13.5	13.7	Jul 1,520 cfs	18.6	21.6
Aug 3,162 cfs	17.7	19.5	Aug 1,792 cfs	18.1	20.8
Sep 2,399 cfs	15.5	17.0	Sep 1,799 cfs	15.7	17.0
1996					
Jun 4,034 cfs	14.8				
Jul 2,283 cfs	17.7				
Aug 1,391 cfs	18.6				
Sep 2,022 cfs	15.0				

*Data were compiled from thermographs maintained by the Recovery Program
+Monthly mean flow at U.S.G.S. gage at Whitewater

There is some general consensus among the scientific community that the West will experience warmer temperatures, longer growing seasons, earlier runoff of snowmelt, and more precipitation occurring as rain rather than snow. Specific predictions for the Gunnison Basin are highly speculative; however, predictions for the overall Colorado River Basin natural flows have ranged between reductions of 6 to 45 percent over the next 50 years (Reclamation 2007). Recent reports (Ray et al 2008) suggest continued warming in Colorado with less clear trends in annual precipitation, although in general lower and earlier runoff is predicted.

In the long-term, the timing and quantity of runoff into the Aspinall Unit may be affected and may affect expected results from the baseline or implementation of the proposed action either in a positive or negative manner. It is possible that the frequency of dry and moderately dry type years will increase, thus reducing the ability of the rivers to move sediment and maintain or improve habitat conditions. Conversely the magnitude of runoff events could become more variable and extreme and still provide conditions for sediment movement.

The hydrology modeling for this assessment does not project future inflows, but rather relies on the historic record to analyze a range of inflows. As discussed elsewhere in this assessment, the inflow to the Aspinall Unit has historically been highly variable and operations under the proposed alternative are planned to address this variability. The study period used in this analysis includes drought periods and both extremely dry and extremely wet years. Because the action being considered does not involve new construction of storage facilities or outlet features, sizing of facilities in relation to future climate is not a consideration. In addition, neither the baseline nor the proposed action itself are viewed as having any effect on climate.

The proposed alternative also includes an adaptive management process, supported by Recovery Program monitoring, to address new information about the subject endangered fish, their habitat, reservoir operations, and river flows. Reclamation will also continue to support multi-faceted research on climate change (Reclamation 2007). If climate results in effects to the listed species or critical habitats that were not considered in this PBA, then Reclamation would reconsult.

3.4.5 Water Rights

Gunnison River Basin water use began in the 19th century with the establishment of numerous irrigation water rights by individuals, organizations, and government agencies. There are more than 5,000 water rights for direct flow diversions presently in use on the river and its tributaries for irrigation, recreation, and municipal and industrial uses. There are an estimated 264,000 acres of irrigated land in the Basin (Colorado Department of Natural Resources 2006). Significant senior diversion rights established prior to 1910 include the Gunnison Tunnel of the Uncompahgre Project (1,300 cfs) located 2 miles downstream from Crystal Dam and the Redlands Diversion (750 cfs), located on the Lower Gunnison River 3 miles upstream from the Colorado River confluence. The 1933 Federal reserved right for the Black Canyon of the Gunnison National Park, also downstream, is currently being quantified and is predicted to be compatible with the proposed action under this PBA.

In addition to water rights for direct diversions and instream flows, there are significant storage and hydropower rights in place on the Gunnison River. The largest single perfected storage right is the 952,000 acre-foot decree for Blue Mesa Reservoir. There are also numerous small reservoirs and several larger Reclamation project reservoirs on tributaries with storage rights: Taylor Park Reservoir on the Taylor River, Silver Jack Reservoir on Cimarron Creek, Crawford Reservoir on the Smith Fork, Paonia Reservoir on the North Fork, Ridgway Reservoir on the Uncompahgre, and Fruitgrowers Reservoir on Alfalfa Run (see Attachment 1).

4.0 GUNNISON RIVER AQUATIC RESOURCES

Prior to water development in the Gunnison River, the upper river supported Colorado River cutthroat trout along with speckled dace, flannelmouth and bluehead suckers, and less common roundtail chubs and perhaps mottled sculpin (Wiltzius 1978); however, by

1900 native cutthroat had been largely replaced in the river and major tributaries by rainbow, brook, and brown trout due to stocking programs and habitat changes. Early in the twentieth century, the Gunnison already was considered a "world-renowned" trout fishery. The lower Gunnison River supported Colorado pikeminnow, razorback suckers, flannelmouth and bluehead suckers, roundtail chubs, speckled dace, sculpin, and perhaps humpback chub and bonytail. The razorback and perhaps the pikeminnow were common in the lower river as late as the 1950's (Burdick 1995).

The fishery of the Gunnison River and its major tributaries upstream from the Aspinall Unit are generally in good condition at the present time with rainbow, brown, and brook trout populations. Native cutthroat trout now occur only in isolated high elevation tributaries. Taylor Park Reservoir supports a rainbow and brown trout, lake trout, and northern pike fishery. The 1975 Taylor Park Exchange Agreement coordinates Taylor Park and Blue Mesa operations and has benefited fisheries of the Taylor and upper Gunnison rivers along with that of Taylor Park Reservoir itself. Fall migration runs of kokanee salmon from Blue Mesa to the Roaring Judy Hatchery on the East River support increasing recreational use.

Blue Mesa, Morrow Point, and Crystal Reservoirs are managed by the Colorado Division of Wildlife (CDOW) as sport fisheries. Public use and active management are limited at Crystal and Morrow Point due to the difficult access; however, the sport fishery at Blue Mesa is one of the largest and most valuable in Colorado. The present fish populations at Blue Mesa consists primarily of kokanee salmon, rainbow trout, lake trout, brown trout, longnose and white suckers, and longnose dace. Northern pike and more recently yellow perch have entered the fishery.

Downstream Morrow Point and Crystal Reservoirs are steep-sided oligotrophic reservoirs with limited access and fisheries. Survival of fish through the Blue Mesa powerplant provides limited "stocking" for Morrow Point and rainbow trout and kokanee are the most common species. Overall, escapement of non-native fish from the Aspinall Unit to the lower Gunnison River is not considered a significant problem because of mortality associated with the series of the three powerplants, depth of outlet works, and the infrequent spillway use at Blue Mesa and Morrow Point.

The Gunnison River from Crystal Dam to the North Fork Confluence has developed into a productive tailwater fishery due to relatively uniform and cold water releases and has been rated as a Gold Medal and Wild Trout (naturally reproducing) fishery by the CDOW. Bluehead suckers are common in this reach and flannelmouth are also present; and non-native longnose and white suckers and carp are found. Reservoir operations provide a minimum flow of at least 300 cfs through the Gunnison Gorge except in extreme droughts and emergencies and this has been beneficial to the fishery since the mid 1980's. Since the fishery is naturally reproducing, relatively stable daily flows during spawning and fry emergence and early development are critical.

Between the Gunnison River's North Fork Confluence and Austin, the river continues to support a quality trout fishery dominated by brown trout. In this reach roundtail chub,

bluehead sucker, flannelmouth sucker, white sucker, and white sucker hybrids become more common. Between Austin and Delta, the trout fishery gradually declines due to warming summer water temperatures and increased turbidity.

Prior to any development, the lower river possibly supported eight fish species, including the bonytail, humpback chub, Colorado pikeminnow, and razorback sucker. By the 1990's, twenty-one species and three hybrids were reported in the lower 75 miles of the Gunnison downstream from the North Fork confluence (Burdick 1995), most with healthy reproducing populations. Seven of these species were native and three were endemic to the Colorado River Basin—the Colorado pikeminnow, humpback chub, and flannelmouth sucker. Other native fish in this reach were the bluehead sucker, speckled dace, roundtail chub, and mottled sculpin. Flannelmouth and bluehead suckers are the most common species.

The river downstream from the Uncompahgre confluence was designated as critical habitat in 1994 for the Colorado pikeminnow and razorback sucker. This reach of the Gunnison retains a healthy reproducing population of native fish and they comprised 79% of a total sample in 1993 surveys (Burdick 1995). This is an unusually high percentage of native fish for a river in the Upper Colorado River Basin and may result in part from the Redlands Diversion (RM 3) which served as a barrier to movement of non-native fish from the Colorado River for most of the 20th century. Numerically the most common fishes sampled were all native fish: bluehead sucker (36%), flannelmouth sucker (29%), and roundtail chub (14%). Kowalski (2008) reported on a more recent 2008 survey that continued to show a healthy population of native fish in the lower Gunnison River.

Floodplain habitat is important to the native fish, and the most extensive floodplain of the Gunnison River is in the 17-mile reach centered near Delta (between River Miles 50 and 67); and this reach has the most complex channel habitats with braided channels, islands, and backwaters (Burdick 1995). Prior to human settlement, the river upstream and downstream from Delta probably supported much more extensive floodplain habitat in this area. Downstream from River Mile 50, the river flows mostly through canyons with the limited floodplain areas developed for orchards, ranches, and gravel pits.

4.1 Discussion of Listed Species

The Service identified 9 endangered, 4 threatened, and 2 candidate species which could be affected by the proposed alternative (Fish and Wildlife Service 2008). Threatened or endangered species are formally listed under Section 7 of the ESA, while candidates are species for which the Service has sufficient information on their status and potential problems to propose them as endangered or threatened, but they have yet to be formally listed. Species of concern are species the Service believes to be vulnerable, but require further study to determine their status.

The species identified by the Service are as follows:

Vegetation

Clay-loving wild buckwheat	*Eriogonum pelinophilum*	endangered
Uinta Basin hookless cactus	*Sclerocactus glaucus*	threatened
Jones' cycladenia	*Cycladenia humilis var. jonesii*	threatened

Wildlife

Yellow-billed cuckoo	*Coccyzus americanus*	candidate
Mexican spotted owl	*Strix occidentalis lucida*	threatened
California condor	*Gymnogyps californianus*	endangered
Southwestern willow flycatcher	*Empidonax traillii extimus*	endangered
Black-footed ferret	*Mustela nigripes*	endangered
Canada lynx	*Lynx Canadensis*	threatened
Gunnison's prairie dog	*Cynomys gunnisoni*	candidate
Uncompahgre fritillary butterfly	*Boloria acrocnema*	endangered

Fish

Colorado pikeminnow	*Ptychocheilus lucius*	endangered
Razorback sucker	*Xyrauchen texanus*	endangered
Humpback chub	*Gila lacypha*	endangered
Bonytail	*Gila elegans*	endangered

Terrestrial wildlife and vegetation species are discussed in Section 5.0.

4.2 Endangered Fish

The Colorado River Basin originally supported a fish fauna with 36 species from 20 genera and 9 families. Of these 36 native species, 64 % were endemic to the basin and only eight were found in both upper and lower portions of the basin. The native fish of the major rivers in the Basin are long-lived and have evolved to live in a system of high spring snowmelt flows, periodic high turbidity, and a wide range of flows.

This PBA addresses the habitat and populations of endangered fish in the Gunnison River and to a lesser extent addresses these fish in the Colorado River downstream from the Gunnison confluence. Recovery Program activities for the Gunnison and Colorado rivers are also discussed. This assessment assumes that improvement in flow regimes in the Gunnison can have positive cumulative impacts on habitat in the Colorado River downstream from the Gunnison confluence. Recovery Program activities for the Gunnison River are discussed; however, it should be noted that there are also many activities under the Recovery Program involving the Colorado mainstem and other tributaries including activities to improve flow conditions, address non-native species, and conduct monitoring and research.

Historical information on the Gunnison River's fish populations is limited and was summarized by Burdick (1995):

> Jordan (1891) collected both Colorado squawfish and razorback sucker from the Gunnison and Uncompahgre Rivers near Delta. He also reported collecting one "bonytail"; however this specimen may have been confused with the more numerous roundtail chub, since they were considered

subspecies until 1970 (Holden and Stalnaker 1975). Chamberlain (1946) reported razorback sucker as common in the Gunnison River downstream from Delta, and also reported Colorado squawfish from the lower Gunnison River. Kidd (1977) reported that a commercial fisherman frequently collected both Colorado squawfish and razorback sucker from 1930 until 1950 near Delta. Some razorback sucker were collected by CDOW during the 1950's, and one was collected near Delta in 1975 (Wiltzius 1978). Anecdotal accounts also suggest razorback sucker may have been abundant in the Delta area. Quartarone (1993) cites local Delta residents reporting both Colorado squawfish and razorback sucker as common in the Delta area and that razorback sucker used to enter the Hartland Diversion Ditch where they became stranded. Kenneth and Wendell Johnson (Personal communication 1993), long-time residents of Delta, indicated that they commonly caught razorback sucker in homemade traps in a flooded oxbow that was connected to the Gunnison River during spring runoff. They also added that they noticed that razorback sucker numbers declined rapidly in the late 1950's. Wiltzius (1978) believed that the Redlands Diversion reduced Colorado squawfish numbers in the Gunnison River by preventing upstream movement from the Colorado River.

4.2.1 Colorado pikeminnow (*Ptychocheilus lucius*)

4.2.1.1 General

The Colorado pikeminnow is the largest member of the minnow family in North America and historically was the top predator fish species in the Colorado River system. This long-lived fish was found throughout warm water reaches of the entire Colorado River Basin downstream to the Gulf of California. Loss of approximately 75 % of its historic range, unknown status in the Upper Basin and threats of further habitat loss prompted listing of Colorado pikeminnow as an endangered species in 1967. Critical habitat was designated on March 21, 1994 (59 FR 13374) as six reaches (1,848 km) of the Upper Colorado River Basin or about 29% of historic habitat, including portions of the Upper Colorado, Green, Yampa, White and San Juan rivers.

Today, Colorado pikeminnow occur in the Green River from Lodore Canyon to the confluence of the Colorado River (Tyus 1991; Bestgen and Crist 2000); the Yampa River downstream of Craig, Colorado (Tyus and Haines 1991); the Little Snake River from its confluence with the Yampa River upstream into Wyoming (Marsh et al. 1991; Wick et al. 1991); the White River downstream of Taylor Draw Dam and Kenney Reservoir (Tyus and Haines 1991); the lower 143 km of the Price River (Cavalli 1999); the lower Duchesne River; the upper Colorado River from Palisade, Colorado, to Lake Powell (Valdez et al. 1982b; Osmundson et al. 1997, 1998); the lower 54 km of the Gunnison River (Valdez et al. 1982a; Burdick 1995); and the lower 2 km of the Dolores River (Valdez et al. 1982a). The Green River and its major tributaries support the largest population of Colorado pikeminnow (2,142 adult fish; Bestgen et al. 2007). The upper

Colorado River adult population increased from 372 in 1991-1994 to 534 fish during 1998-2000 (Recovery Program 2006b).

4.2.1.2 Distribution and Abundance in the action area

While data is scarce, it does appear that the Gunnison historically supported a population of pikeminnow that at some point in time declined markedly. Wiltzius (1978) summarized written and anecdotal reports on this species; information on the relative abundance of the species was not consistent within these reports. Surveys since 1980 revealed only a very small remnant population in the Gunnison River (Valdez et al. 1982a; and Wick et al. 1985).

More recently, Burdick (1995) captured 5 adult pikeminnow during the 1992-1994 period. All fish reported by Burdick (1995) and Valdez et al. (1982a) were captured between RM 17 and 48, with most occurring near RM 33. During 2006 sampling, 2 wild adult pikeminnow were captured (McAda and Burdick 2006), although none were collected during 2007 (McAda and Burdick 2007). Figure 3 presents recent distribution information.

Larval Colorado pikeminnow were collected in very small numbers downstream from the Redlands Diversion in 1992, 1995, and 1996 and larval fish were collected near RM 29 and RM 5.5 in the mid-1990s (Osmundson and Kaeding 1989; Anderson 1994; Burdick 1995; and Anderson 1999). A possible spawning area was located between RM 32 and 33 based on congregation of radio-tagged fish and collection of larvae downstream. In 2006, a pikeminnow originally tagged in 1993, was captured at RM 32.3 in July.

Although pikeminnow use the entire Colorado River above Lake Powell, there are distinct differences in distribution among age classes. In general, most adults are found in the upper reaches of the Colorado River and most sub-adults, juveniles, and young-of-year (YOY) are found in the lower reaches (McAda 2003; Valdez et al. 1982b; Archer et al. 1985; McAda and Kaeding 1991; Osmundson et al. 1997). This difference in distribution may relate to increased abundance of appropriate-sized prey in upstream reaches (Osmundson 1999). Studies involving catch-rates indicate that the Gunnison River has a relatively high population of fish that could serve as potential prey for pikeminnow (Osmundson 1999).

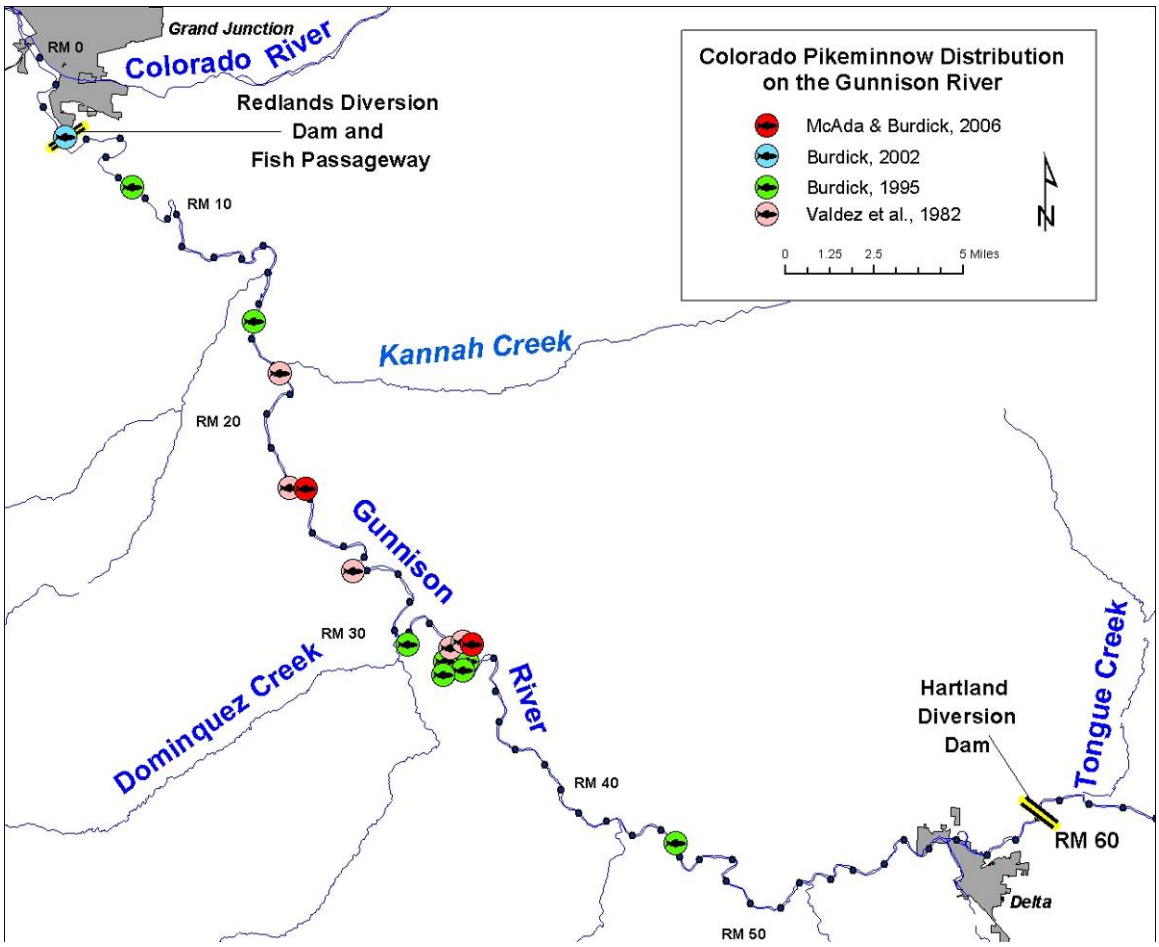


Figure 3. Recent distribution, Colorado pikeminnow, Gunnison River.

4.2.1.3 Life history

Colorado pikeminnow in the upper Colorado River sub basin live to at least 12 years (Hawkins 1992). Larvae at hatching are 6.0–7.5 mm long and grow under laboratory conditions at about 13 mm/month (Hamman 1981). Mean annual growth rate of fish from the upper Colorado River aged 3–6 years ranged from 32.2 (age 6) to 82.0 (age 3) mm/year and declined to 19.8 mm/year for fish 500–549 mm total length (TL) (Osmundson et al. 1997); fish 550 mm and larger grew an average of 9.5 mm/year. Average-sized Colorado pikeminnow in the upper basin are 450–550 mm TL and weigh 1–2 kg.

The Colorado pikeminnow is an obligate warm-water species that requires relatively warm temperatures for spawning, egg incubation, and survival of young. Hatchery-reared males became sexually mature at 4 years of age and females at 5 years. Spawning activity begins after the peak of spring runoff during June-August at water temperatures typically 16°C or higher (Vanicek and Kramer 1969; Hamman 1981; McAda 2003; Muth et al. 2000). Spawning in the Gunnison River, based on limited larvae collection, ranged from early June to mid-July. Colorado pikeminnow are broadcast spawners that scatter

adhesive eggs over cobble substrate which incubate in interstitial spaces. Hatching success is greatest at 20–24°C with incubation time of 90–121 hours (Hamman 1981; Marsh 1985).

Survival and recruitment of Colorado pikeminnow is pulsed, as a strong year class appears and is reflected in the size composition of the population over time. This "storage effect" (Gilpin 1993) enables long-lived populations to maintain themselves despite several years of failed or low reproductive success. Greatest cohort strength in the upper Colorado River (i.e., 1986, 1996) occurred 1–2 years after high river flows, indicating that high velocities are needed to flush excessive sediments and organics from interstices of spawning cobbles, which otherwise suffocate eggs and reduce survival of larvae. McAda and Ryel (1999) noted that especially strong cohort strength in the Colorado River was related to high spring peak flows (ca. 50,000 cfs) during the previous year and moderately high spring peaks (30,000 to 40,000 cfs) during the year in which the fish were produced. Successful cohorts during high flows may be precluded by delayed warming of the river which causes delayed spawning, poor age-0 survival, and/or displacement of larvae beyond optimal rearing habitat (Thompson et al. 1991; Converse et al. 1998), but these high peaks may be necessary to provide optimal spawning conditions during the following year.

Studies of overwinter survival show a significant relationship between densities of age-0 fish in fall and spring, suggesting that high spawning success and egg and larval survival by fall (i.e., 3–4 months of age) largely determine cohort strength (Valdez et al. 1999; McAda and Ryel 1999). Overwinter survival also influences cohort strength, but the linkage to environmental correlates (e.g., flow variability, river temperature and ice formation, average backwater depth, and non-native fish density) is unclear. Overwinter survival was related to backwater depth with higher survival (85%) in backwaters deeper than 120 cm and lowest survival (18%) in backwaters less than 30 cm deep (Valdez et al. 1999). In the upper Colorado River, overwinter survival ranges from 7–77% (mean, 49%; McAda and Ryel 1999). Survival rates of adults >550 mm TL from the upper Colorado River is about 85% (Osmundson et al. 1997).

Backwaters and other low-velocity shoreline habitats in alluvial reaches of the upper Colorado, Green, and San Juan rivers are important nursery areas for larval and juvenile Colorado pikeminnow (Tyus 1991; Holden 2000; McAda 2003; Muth et al. 2000), and researchers believe that non-native fish species in those habitats limit the success of Colorado pikeminnow recruitment (e.g., Muth and Nesler 1993; Bestgen et al. 1997; McAda and Ryel 1999; Valdez et al. 1999). Non-native fish assemblages in these habitats are dominated by fathead minnow, sand shiner and red shiner. McAda and Ryel (1999) demonstrated that abundance of these non-native species during both summer (larvae) and autumn (juvenile and adults) was inversely correlated with magnitude of the previous spring peak flows, whereas relationship of young-of-year native fish to spring peak flows was either positive or statistically not significant.

Young Colorado pikeminnow remain near nursery areas for the first 2–4 years of life, and then move upstream to recruit to adult populations and establish home ranges

(Osmundson et al. 1998). Adult Colorado pikeminnow remain in home ranges during fall, winter, and spring and may move considerable (up to 950 km) distances to and from spawning areas in summer (Irving and Modde 2000) . Individuals move to spawning areas shortly after runoff in early summer, and return to home ranges in August and September (Tyus 1990; Irving and Modde 2000). Long range movement of Colorado pikeminnow among the Green and Colorado rivers suggests that the upper basin population is panmictic with evidence of source/sink dynamics (Gilpin 1993).

4.2.1.4 Colorado Pikeminnow Habitat

Colorado pikeminnow live in warm-water reaches of the Colorado River mainstem and larger tributaries, and require uninterrupted stream passage for spawning migrations and dispersal of young. Throughout most of the year, juvenile, subadult, and adult Colorado pikeminnow utilize relatively deep, low-velocity eddies, pools, and runs that occur in nearshore areas of main river channels (Tyus and McAda 1984; Valdez and Masslich 1989; Tyus 1990, 1991; Osmundson et al. 1995). In spring, however, Colorado pikeminnow adults utilize floodplain habitats, flooded tributary mouths, flooded side canyons, and eddies that are available only during high flows (Tyus 1990, 1991; Osmundson et al. 1995). Such environments may be particularly beneficial for Colorado pikeminnow because other riverine fishes gather in floodplain habitats to exploit food and temperature resources, and may serve as prey. Such low-velocity environments also may serve as resting areas for Colorado pikeminnow. River reaches of high habitat complexity appear to be preferred.

During most of the year, distribution patterns of adults are stable (Tyus 1990, 1991; Irving and Modde 2000), but distribution of adults changes in late spring and early summer, when most mature fish migrate to spawning areas (Tyus and McAda 1984; Tyus 1985, 1990, 1991; Irving and Modde 2000). High spring flows provide an important cue to prepare adults for migration and also ensure that conditions at spawning areas are suitable for reproduction once adults arrive. Specifically, bankfull or much larger floods mobilize coarse sediment to build or reshape cobble bars, and they create side channels that Colorado pikeminnow sometimes use for spawning (Harvey et al. 1993). Spawning occurs in gravel-cobble substrates in riffles and runs, and adjacent pools or backwaters can be used for resting or staging. Spawning habitat in the action area is located in meandering, alluvial reaches susceptible to considerable change during years of high flows (McAda 2003). Thus, while spawning doesn't necessarily occur in the same area from one year to the next, six sites in the action area have been identified as potentially important areas for spawning activity:

1) The Colorado River reach immediately above the Gunnison River confluence
2) Two Colorado River reaches below the Gunnison river and above Westwater Canyon
3) The Colorado River downstream from Westwater Canyon near Fish Ford
4) The Gunnison River immediately below Redlands Diversion
5) The Gunnison River near RM 32

Cobble-gravel bar complexes that typify these sites are found at many locations in the upper Colorado River basin, however, and spawning activity can vary spatially from one year to the next.

Eggs are broadcast on cobble substrates in riffles and runs and incubate in the interstitial spaces for 4-7 days before hatching. The new larvae remain in the gravel/cobbles for about one week and then emerge and enter the river current. After emerging, Colorado pikeminnow larvae drift downstream to backwaters in sandy, alluvial regions, where they remain through most of their first year of life (Holden 1977; Tyus and Haines 1991; Muth and Snyder 1995). Backwaters and the physical factors that create them are vital to successful recruitment of early life stages of Colorado pikeminnow, and age-0 Colorado pikeminnow in backwaters have received much research attention (e.g., Tyus and Karp 1989; Haines and Tyus 1990; Tyus 1991; Tyus and Haines 1991; Bestgen et al. 1997). It is important to note that these backwaters are formed after cessation of spring runoff within the active channel and are not floodplain features. Colorado pikeminnow larvae occupy these in-channel backwaters soon after hatching. They tend to occur in backwaters that are large, warm, deep (average, about 0.3 m in the Green River), and turbid (Tyus and Haines 1991). Recent research (Day et al. 1999, 2000; Trammell and Chart 1999a, 1999b) has confirmed these preferences and suggested that a particular type of backwater is preferred by Colorado pikeminnow larvae and juveniles. Such backwaters are created when a secondary channel is cut off at the upper end, but remains connected to the river at the downstream end. These chute channels are deep and may persist even when discharge levels change dramatically. An optimal river-reach environment for growth and survival of early life stages of Colorado pikeminnow has warm, relatively stable backwaters, warm river channels, and abundant food (Muth et al. 2000).

Summer water temperatures at Whitewater only infrequently exceed optimal ranges for Colorado pikeminnow growth, and upstream reaches appear to be too cool for pikeminnow reproduction (see Table 10 and Attachment 6). Due to cool releases from the Aspinall Unit, Gunnison River summer temperatures in critical habitat were about 3 degrees °C cooler than river reaches in other parts of the Colorado River Basin that have relatively large populations of endangered fish. Osmundson (1999) considered the potential for extending the range of endangered fish in the Gunnison River, and determined that distribution of Colorado pikeminnow was temperature-limited and extended only to about 33 miles upstream of the Colorado River confluence (Dominguez Creek – Peeples Orchard). Cooler water upstream does not preclude fish from using upper reaches but the cooler temperatures can interfere with life processes such as reproduction and can lower growth rates. Osmundson (1999) reported good prey and habitat conditions upstream, but only sporadic use by Colorado pikeminnow and hypothesized that water temperature may reduce the upstream use.

4.2.1.5 Flow and habitat maintenance

The relationship between flow regimes and habitat maintenance was summarized in McAda (2003):

Spring
- Increasing flows cue fish to prepare for migration and spawning
- High flows inundate floodplain habitats to provide warm food-rich environments for growth and gonadal maturation
- High flows scour vegetation on banks and side channels to maintain habitat complexity
- High flows scour sediment from the cobbles and gravels to provide suitable location for eggs and larvae
- High flows mobilize the bed in runs and riffles; fines are flushed from the substrate and interstitial spaces
- High flows transport sediment and build in channel bars for backwater habitat
- High flows reduce non-native predators and competitors

Late Spring/Early Summer
- Declining flows and increasing water temperatures initiate migration and spawning
- Flows are sufficient to provide migration routes
- Flows are sufficient to prevent sedimentation of eggs and larvae

Summer
- Base flows maximize preferred habitat and sufficient depth for movement
- Base flows maximize backwater habitats available to young fish

Winter
- Base flows maximize preferred habitat and sufficient depth for movement and resting
- Base flows maximize backwater habitats available to young fish

4.2.2 Razorback sucker (*Xyrauchen texanus*)

4.2.2.1 General

The razorback sucker is a large catostomid and is endemic to the Colorado River. It is a long-lived fish and historically was found throughout warm water reaches of the entire Colorado River Basin downstream to the Gulf of California. By the 1990's, the largest riverine population was found in the middle Green River. The razorback sucker was listed as endangered under the ESA on October 23, 1991 (56 FR 54957). Critical habitat was designated on March 21, 1994 (59 FR 13374) as 15 reaches (2,776 km) of the Colorado River System or about 49% of historic habitat, including portions of the Colorado, Green, Yampa, Duchesne, White, Gunnison, and San Juan rivers in the upper basin, and portions of the Colorado, Gila, Salt, and Verde rivers in the lower basin. A recovery plan was approved in 1998 and amended and supplemented with recovery goals in 2002 (U.S. Fish and Wildlife Service 2002d).

4.2.2.2 Distribution and abundance in the action area

It appears that razorback sucker was once abundant in the Gunnison River, yet significantly declined in the second-half of the 20th century, perhaps becoming totally expatriated from the river by the 1990's. Historical information on the Gunnison River's fish populations is limited and was summarized by Burdick (1995) (Section 4.2).

Prior to Recovery Program activities, the last wild adults were captured near Delta in 1981 (Holden et al. 1981). Extensive sampling after that failed to capture any more individuals of the species in the Gunnison (McAda 2003). Since 1994, over 50,000 razorback sucker (ranging from 100 to 300 mm in length) have been stocked in the Upper Colorado River Basin (Burdick 2003). Most stocking occurs in the Colorado River, although approximately 3,000 razorback suckers per year are currently stocked in the Gunnison River (Tom Czapla, personal communication; Burdick 2003). Fish stocked at a minimum of 200 mm total length are recaptured most frequently. Stocked razorbacks are surviving in the Gunnison River and are reproducing based on captures of larval fish; and razorback sucker larvae are surviving through the first years (Recovery Program, 2008). The May 2008 Recovery Program Assessment indicated "Larvae of stocked razorback are potentially surviving through the first year in the Gunnison River. Juveniles captured at Redlands were either produced in the wild or were stocked into Butch Craig."

Figure 4 presents the current distribution of razorback sucker in the action area. Recent surveys of stocked razorback sucker in the Gunnison River indicate stocked fish have been at large for 5-11 years (McAda and Burdick 2006, 2007). Repeat observations of razorback sucker in backwater habitats were made near RM 51.4 during 2006 and 2007, although one fish was caught upstream of the Delta highway bridge and one near the mouth of Roubideau Creek. Overall there is little evidence of successful recruitment of this species in the Upper Colorado River Basin, although recent surveys indicate that stocked razorback sucker are spawning successfully in the Gunnison and Colorado rivers (Osmundson and McAda 2006, 2007).

In the Colorado River, most razorback suckers have been captured in the Grand Valley reach of the Colorado River (Loma to Palisade) near the confluence of the Gunnison and Colorado rivers (McAda 2003). In the late 1970's, razorback sucker were frequently captured from gravel pit ponds connected to the mainchannel Colorado River (Kidd 1977; McAda and Wydoski 1980). Their abundance in those areas has decreased considerably since that time. Only 11 wild razorback sucker were captured from the

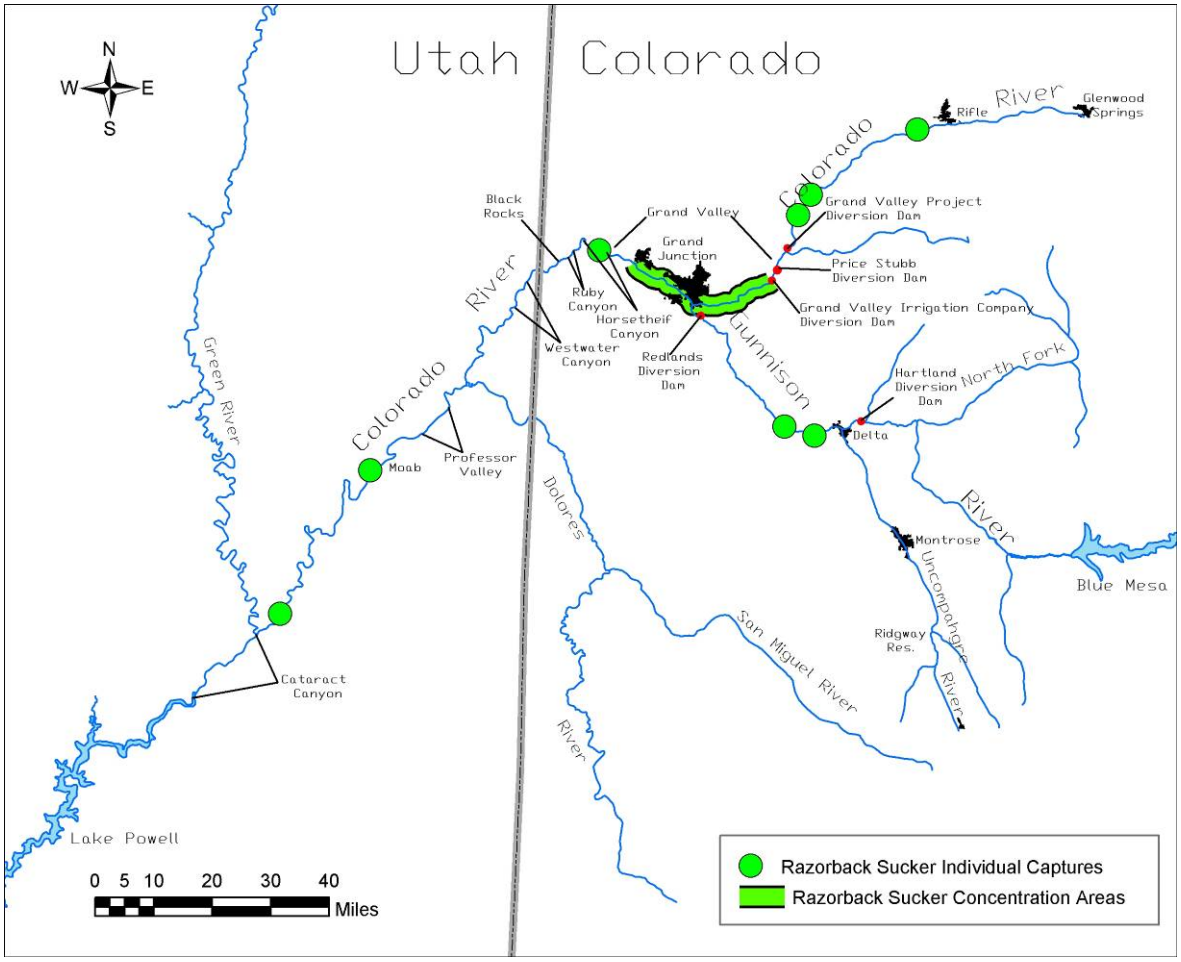


Figure 4. Razorback sucker distribution information, Colorado and Gunnison rivers.

Colorado River since 1990 (Osmundson and Kaeding 1991), all of which were brought into captive propagation programs.

Razorback sucker were also captured in considerable numbers near DeBeque in 1974-1975 by Kidd (1977). No razorback sucker captures have been made in that area since, although Burdick (1992) documented low numbers of fish in gravel pit ponds upstream and downstream of DeBeque. Few razorback sucker occur below Loma.

4.2.2.3 Life history

Adult razorback sucker attain a maximum size of about 1 m TL (5–6 kg; (Minckley 1973) and can exceed 40 years in age (McCarthy and Minckley 1987), although most individuals are less than 650 mm. Growth of razorback sucker is variable, depending on environmental conditions. Razorback sucker reared in hatchery aquaria were 150 mm TL in their first year of life (Valdez et al. 1982b), but fish reared in outdoor ponds near Vernal, Utah, grew to 127–156 mm TL in 4 months (Bestgen 1990). Fish reared in riverside ponds near Grand Junction, Colorado, grew from an average of 54.8 mm TL to 307 mm TL in 6 months (Osmundson and Kaeding 1989).

Most observations of razorback sucker reproduction in the Upper Colorado River Basin have been made in the Green River near Jensen, Utah. These fish spawn in May–June at temperatures of 6–19°C in velocities <1.0 m/s and depths of <1.0 m, near the upstream end of large gravel-cobble riffles (McAda and Wydoski 1980; Tyus and Karp 1990; Snyder and Muth 1990). Spawning sites occur in broad alluvial, flat-water regions with large cobble riffles and large riverside bottomlands as nursery areas immediately downstream (Bestgen 1990; Tyus and Karp 1989, 1990). Adults congregate in deep pools and runs near large cobble bars and spawn in April–May with rising water levels and increasing temperatures. Due to high reproductive potential and great longevity (McCarthy and Minckley 1987), razorback sucker may not spawn every year.

Newly hatched larvae (7-10 mm) drift into warm and highly productive flooded bottomlands, where they remain until the river recedes. The association of spawning during the ascending limb of the spring hydrograph and subsequent transport of newly hatched larvae into flooded bottomlands appears to be a critical relationship to the survival of this species that has been disrupted with regulation of high spring flows. Survival of newly hatched larvae appears to be the limiting factor for razorback suckers in the Upper Colorado River Basin (Tyus 1998). Absence of flooding that historically created flooded bottomlands in the Green, Yampa, and Colorado Rivers has limited nursery areas for newly hatched larvae (Bestgen 1990; Tyus and Karp 1990; Tyus 1998). Modde et al. (1996) correlated successful razorback recruitment in the Green River with high spring flows which reconnect floodplain habitats to the mainchannel.

Razorback suckers can migrate extensively to and from spawning sites in spring, but tend to move very little at other times of the year. As recently as the early 1980s, large numbers of adults were seen congregated at tributary mouths on the Green River (Tyus et al. 1982) and in gravel pits and large flooded bottomlands in the Colorado River (Valdez et al. 1982b). Except for spawning migrations, razorback suckers are relatively sedentary, moving only a few km over several months (Tyus 1987; Tyus and Karp 1990). Razorback sucker in the upper basin live sympatrically with about 20 species of warmwater, non-native fishes (Tyus et al. 1982; Lentsch et al. 1996) that are potential predators, competitors, and vectors for parasites and diseases. Hawkins and Nesler (1991) identified red shiner, common carp, fathead minnow, channel catfish, northern pike, and green sunfish as the non-natives considered by Upper Colorado River Basin researchers to be of greatest concern because of their suspected or documented negative interactions with native fishes. Sand shiner, white sucker, black bullhead, smallmouth bass, and largemouth bass were identified by Hawkins and Nesler (1991) as non-natives of increasing concern because of their increasing abundance, habitat preferences, and/or piscivorous habits. Lentsch et al. (1996) identified existing threats to native fishes in the upper basin from six species of non-native fishes including red shiner, common carp, sand shiner, fathead minnow, channel catfish, and green sunfish.

4.2.2.4 Razorback sucker habitat

Razorback suckers use different habitats with season and age (Valdez et al. 1987; Bestgen 1990; Tyus and Karp 1990). Habitat of (post-larval) juveniles has not been well

documented because of small numbers of individuals captured in the wild. Juveniles (59–124 mm TL) have been captured in backwaters, tributary mouths, and flooded bottomlands (Taba et al. 1965). Adults over-wintered in deep runs and pools (0.6–1.4 m deep, 0.03–0.33 m/s) in alluvial and canyon regions of the Green River (Valdez and Masslich 1989), but often move into riverside gravel pits (Valdez et al. 1982b) and large flooded bottomlands during spring runoff for feeding and shelter from high mainstem flows (Tyus and Karp 1990). Adults in spring used deep, near-shore runs (0.6–3.4 m deep, 0.3–0.4 m/s), moved to large cobble islands (0.63 m deep, 0.74 m/s) for spawning, and shifted to shallow, slack water near mid-channel sandbars in summer (<2 m deep, 0.5 m/s) (Tyus 1987).

Temperature is an important aspect of habitat for razorback suckers. Thermal preference for adults was 22.9–24.8°C, based on electronic shuttle box studies, and lower avoidance temperature was 8.0–14.7°C and upper avoidance temperature was 27.4–31.6°C (Bulkley and Pimentel 1983). It was concluded from this study that alterations in year-round water temperature outside the range of 12.0–29.0°C should not be allowed if preservation of habitat for razorback suckers is a consideration.

Based on recent larval fish survey, spawning activity of stocked fish is taking place in the Gunnison River between the Redlands Diversion and Delta (Osmundson and McAda 2007). Larvae have been collected during most years since 2002, indicating successful reproduction. Locations of specific spawning sites have not been identified to date. Consequently, while the Recovery Program has identified and prioritized floodplain wetlands, their active restoration and management depends on proximity to these yet unknown spawning locations (Valdez and Nelson 2006). High priority floodplain habitats in the action area are identified in Section 2.1.1.

The relationship between flow regimes and habitat maintenance was summarized in McAda (2003):

<u>Spring</u>

- Increasing flows cue fish to migrate to spawning areas and trigger reproduction
- High flows inundate floodplain habitats to provide warm food-rich environments critical for larval fish and to provide river-floodplain connections
- High flows scour vegetation on banks and side channels to maintain habitat complexity
- High flows scour sediment from the cobbles and gravels to provide suitable location for eggs and larvae
- High flows mobilize the bed in runs and riffles; fines are flushed from the substrate and interstitial spaces
- High flows transport sediment and build in channel bars for backwater habitat
- High flows reduce non-native predators and competitors

<u>Late Spring/Early Summer</u>

- Declining flows allow increasing water temperatures
- Flows are sufficient to provide migration routes for adults and larvae

Summer
- Base flows maximize preferred habitat and sufficient depth for movement
- Base flows maximize backwater habitats available to young fish

Winter
- Base flows maximize preferred habitat and sufficient depth for movement and resting
- Base flows maximize backwater habitats available to young fish

4.2.3 Humpback chub (*Gila cypha*)

4.2.3.1 General

The humpback chub is a mid-sized cyprinid endemic to the Colorado River basin, generally found in deep-water canyon-bound reaches of the river system. Humpback chub were first listed as federally endangered on March 11, 1967 (32 FR 4001) and is protected under the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 *et seq.*). Critical habitat was designated on March 21, 1994 (59 FR 13374) as seven reaches (610 km) of the Colorado River System or about 28% of historic habitat

4.2.3.2 Historical distribution and abundance in the action area

Within the action area, humpback chub are most numerous in the Westwater Canyon and Black Rocks area of the Colorado River (McAda 2003). Westwater Canyon is an 18 mile reach comprised of rapids, deep pools and strong eddies; Black Rocks is a 1 mile reach just upstream of the Colorado-Utah state line. The two populations are generally considered isolated, although some limited movement between the two has been documented (Valdez and Clemmer 1982; Kaeding et al. 1990; Chart and Lentsch 1999a; McAda 2002b). The Westwater Canyon population has declined from 6,985 adults during 1993-1996 (Chart and Lentsch 1999) to about 2,413 fish in 2003 (Hudson and Jackson 2003; Recovery Program 2006b). Similarly, the Black Rocks population has declined from 764 fish in 1998 to 478 fish in 2003 (McAda 2007). In 2008, the Recovery Program estimated a population of about 3,000 adults in the Black Rocks and Westwater Canyon core populations (Recovery Program, 2008).

The Gunnison River has never been considered habitat for the humpback chub. Burdick (1995) captured one specimen in a canyon bound reach at RM 22. The Gunnison Gorge contains some habitat similar to other river reaches in the basin that support humpback chub, but only roundtail chub were documented during pre-impoundment surveys (Wiltzius 1978).

4.2.3.3 Humpback chub habitat

Canyon-bound reaches of deep water such as at Black Rocks and Westwater canyons are preferred habitat of humpback chub adults (McAda 2003). They appear to prefer low-velocity habitats adjacent to the main channel, primarily eddies. Humpback chubs spawn

in late spring or early summer at, or shortly after the spring peak, generally mid-June to late July. Little is know about spawning but limited data indicates that spawning occurs in gravel and cobble substrates. Larval drift does not appear to be as significant as with the pikeminnow and razorback.

4.2.4 Bonytail (*Gila elegans*)

4.2.4.1 General

The bonytail is a large cyprinid fish endemic to the Colorado River and is the rarest of the four big river endangered fishes in the Colorado River Basin; wild populations are considered nearly extinct.

4.2.4.2 Historical distribution and abundance

The Gunnison River has never been confirmed as habitat for this species; however, early sampling and anecdotal information suggests the species was common in the Green and Colorado Rivers in the early 20th century (McAda 2003). The Fish and Wildlife Service (2002) cited one capture in the Gunnison River near Delta by Jordan (1891), although identification of this specimen has been questioned and 5 captures in the mainstem Colorado River in the 1980's. Therefore it is possible that the species once utilized the Gunnison River. In recent years the species has been stocked in backwaters adjacent to the river near Whitewater and Kowalski (2008) reported collecting 2 bonytail from the river near the backwater in the summer of 2008.

4.2.4.3 Bonytail habitat

Because the bonytail is so rare in the wild, little is known about habitat preferences (McAda. 2003). Limited captures have occurred in canyon sections such as Cataract Canyon and Black Rocks on the Colorado and canyon sections of the Green River. Because the bonytail evolved in the same system as the pikeminnow and razorback, it is assumed that similar flow regimes would be beneficial to all species.

4.3 Historical Habitat Changes

The baseline habitat of the four listed species has changed significantly over the last 125 years. Sections of this report document the significant changes in the hydrology, geomorphology, and water quality, including water temperature, of the Gunnison River and further information is found in McAda (2003). It is not entirely clear when populations of endangered fish declined in the Gunnison River and this makes the direct cause of the decline difficult to identify. Habitat changes related to flow changes, non-native fish, migration blockage, water quality, and river channelization all may play a part in the decline of the species.

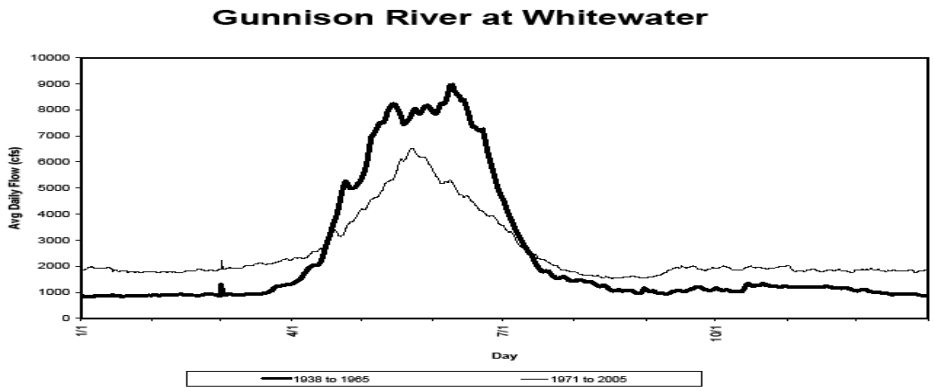
River flows

Pitlick et al. (1999) reported that since 1950, annual peaks of the Colorado River near Cameo have decreased by 29 % and annual peaks of the Gunnison near Grand Junction decreased by 38 %. Mean annual flows of the Gunnison have not changed significantly since 1950, while annual flows of the Colorado River have decreased significantly due to transmountain diversions. As an indication of increased summer and winter flows following construction of the Aspinall Unit, the percentage of months flows exceed 300 cfs downstream from the Redlands Diversion have increased from 43 to 65 % for August; 32 to 85% in September; 49 to 88% in October; 64 to 83% in December; 12 to 79% in January; 20 to 80% in February; 43 to 82% in March; and 85 to 90% in April.

Figure 5 provides a generalized picture of monthly flow changes in the Gunnison River over various time periods at Whitewater and in the Black Canyon. Long-term changes in climatic conditions, along with increased diversions for irrigation explain some of the differences in annual runoff at the Gunnison Tunnel. For example, the average annual natural flow of the Gunnison River at the Gunnison Tunnel between 1938 and 1965 was 185,940 af less than the period between 1911 and 1937. Overall, the 1992-2003 period was drier than the other periods. In addition, average Gunnison tunnel irrigation diversions increased by about 83,000 af per year in the same 1938-1965 period. However, changes in the seasonal distribution pattern of flows depicted by the hydrographs are due mostly to reservoir storage patterns.

Changes in flow regimes affected backwater habitats, channel maintenance, sediment movement, and other habitat factors. McAda (2003) summarized investigations into the influence of water development on channel morphology and river habitat:

> Pitlick et al. (1999) documented large-scale morphological changes that have occurred in parts of the Gunnison (lower 60 mi) and Colorado rivers (15-mi reach, 18-mi reach, and Ruby-Horsethief Canyon) by comparing aerial photographs taken in 1937, 1954, 1968, 1993, and 1995. The largest changes were in the 15- and 18-mi reaches where the Colorado River is largely unconstrained and still free to move about the floodplain (Pitlick et al. 1999). Although main channel and side channel area increased in some river segments, the overall trend was a decrease in surface area with main channel area decreasing by 15%, backwater area decreasing by 9% and side channel area decreasing by 26% (Pitlick et al. 1999). The reduction in side channel habitat may be especially important because side channels increase habitat diversity even though they comprise a small percentage of the river. Complex river reaches (i.e. multi-thread reaches) provide a variety of habitats in a small area and are preferred over single-thread reaches by adult Colorado pikeminnow. The 15- and 18-mi reaches provide most side-channel habitat in the Colorado River (Pitlick and Cress 2000) and contain a much higher number of adult Colorado pikeminnow than other, much longer reaches of the river.



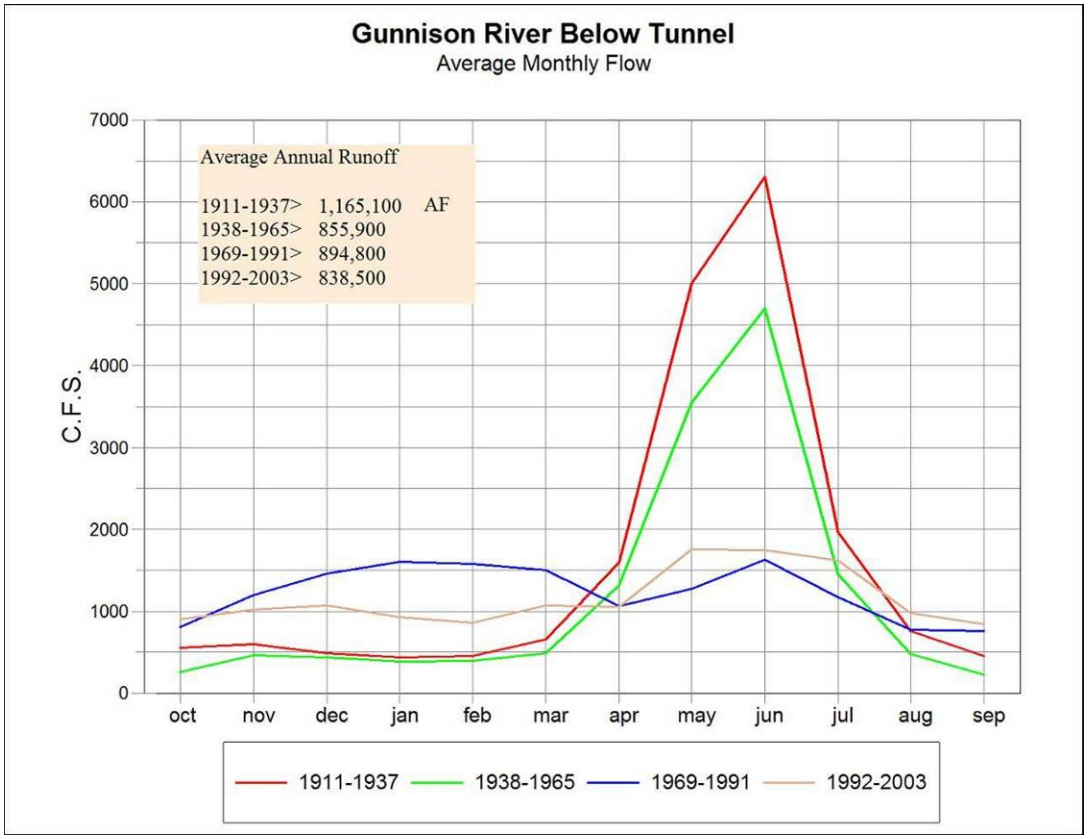


Figure 5. Generalized presentation of average monthly flow changes, Gunnison River at Whitewater and in Black Canyon.

Change in the channel area of the Gunnison River was less than observed for the Colorado River, but results were probably underestimated because of large differences in river flow when the two sets of aerial photographs were taken (Pitlick et al. 1999). Also the Gunnison River is more incised than the Colorado River and less change would be expected. Pitlick et al.

(1999) documented little change in main channel and side channel area, but showed a 15% decrease in island area between 1937 and 1995.

Geomorphology

While spring peak flows have decreased in the rivers, sediment inflow to the rivers apparently has not (Pitlick et al. 1999, Pitlick and Cress 2000). These two interacting factors reduce channel complexity as side channels gradually fill with sediment. Overall the rivers can become narrower and more simplified. This tendency is magnified by construction of dikes and other channel control structures. According to Pitlick et al. (1999), the period from the late 1950's through the 1970's had lower peak flows and similar annual sediment loads than occurred before or after that period, and this may have resulted in substantial sediment deposition in fish habitat, thus affecting spawning areas and backwaters. Very high flows, such as occurred in 1983 and 1984 tend to reverse the process temporarily.

Sediment deposition may also adversely affect the carrying capacity of rivers for the endangered fishes by reducing periphyton and macroinvertebrates that are important parts of the riverine food web (Osmundson et al. 2002) and Lamarra (1999).

Migration

Prior to water development in the basin, it is assumed that fish freely moved between the Gunnison and Colorado rivers; however, early water projects cut off these movements. The Redlands Diversion, located 3 miles upstream from the Colorado River confluence, was a barrier to upstream fish migration to the Gunnison River for nearly 100 years; and, during base flow periods, diverted a significant portion of the river and also presumably larval and adult fish. The Hartland Diversion, upstream from Delta, to a lesser extent, was also a barrier to migration. On the mainstem Colorado River migration was precluded by Boulder Dam in 1935 and by subsequent dams including Glen Canyon. Diversion Dams on the Colorado River upstream from the Gunnison confluence in Mesa County Colorado also blocked migration. In the last decade, fish passage has been provided around the Redlands Diversion and through the diversions on the Colorado River upstream from the Gunnison confluence. In addition fish screens have been constructed at major canals to reduce losses of fish to canals.

Water quality

While records are sparse, it is likely that water quality conditions in the early mining/timbering/grazing days were extreme and may have significantly affected fisheries. Mining in the headwaters and uncontrolled grazing in early settlement years affected water quality and streamflows, while large-scale irrigation in valleys underlain by Mancos shale resulted in return flows with increased salinity and selenium levels. Hamilton (1999) cited very high levels of selenium in the Colorado River basin early in the 20th Century. According to Hamilton, "In the 1930's selenium concentrations in various drains, tributaries and major rivers in the upper and lower Colorado River basins

were in the 100s and 1000s of (ppb)." Levels of 80 ppb were reported from the mouth of the Gunnison River (NIWQP display based on Hamilton 1999).

The historical effect and the effect of present levels of selenium related to the recovery of endangered fish in the Green, Colorado, and Gunnison rivers has been a debated topic. Hamilton et al. (2000) suggested that survival and recruitment of razorback larvae in the Green River was limited due to selenium concentrations. Hamilton (1999) also hypothesized on the possible role of selenium in the decline of endangered fish species in the Colorado River Basin:

> In retrospect, the extremely elevated selenium concentrations in the Colorado, Gunnison, Uncompahgre, and San Juan rivers and their tributaries from the mid-1930's, which presumably started in the 1890s when irrigation activities began, would be expected to have had a devastating effect on native fish, based on adverse effects demonstrated in recent studies with endangered fish and numerous other species. This adverse effect was recognized indirectly as the disappearance around the 1910 to 1920 period of large-river fish such as Colorado pikeminnow and razorback sucker before large dams were constructed in the upper Colorado River basin. In the lower basin these fish were found until 1911 in abundance in irrigation ditches, but by 1925 to 1930 were considered scarce. The statement of Minckley et al. (1991) about the striking historical absence of young razorback sucker in collections suggests reproductive failure probably was occurring, i.e., no recruitment of young fish to the population, which is one of the well documented effects of selenium exposure. There is little doubt that the construction of mainstem reservoirs and introduction of exotic species have contributed to the decline of endangered fish in the Colorado River. There is now evidence that selenium, historically and currently, may be contributing to the endangerment of fish in the Colorado River basin.

In contrast to this study however, the Recovery Program also sponsored evaluations of selenium contamination on endangered fish during the mid- to late 1990's. Beyers and Sodergren (1999) conducted laboratory experiments on effects of direct exposure to dissolved and dietary selenium on survival and growth of razorback sucker larvae. They observed no changes in survival or growth or larvae due to exposure to selenium in any form or concentration, although dietary concentrations were likely insufficient to elicit a response. Predictions from this study were later validated by exposing razorback sucker larvae to water collected from three locations in the Colorado River near Grand Junction and food organisms cultured in that water, including higher levels of dietary selenium than used in the laboratory study (Beyers and Sodergren 2001a, b). As with the laboratory study, significant negative biological effects of selenium were not detected in razorback larvae. However, while the authors noted that selenium could be harmful if effects of maternal selenium transfer were considered, they recommended that the Recovery Program consider all threats to razorback sucker recruitment and survival (i.e.,

loss of physical habitat, altered thermal and hydrologic regimes and interactions with non-native fish) in their formulation of management actions.

Other studies concluded that most of the evidence implicating selenium is circumstantial and that "neither the historical record nor the technical literature consistently supports the emphasis given selenium toxicity (Korte 2000).

Much like other deep-release dams, Blue Mesa Dam has decreased the summer temperatures of the Gunnison River and increased winter temperatures. Summer temperatures below the North Fork have declined by as much as 10 degrees C in the summer (Stanford 1994), but due to rapid warming rates below that point temperatures near Delta are only 2 degrees C below pre-dam levels (McAda and Kaeding 1991). Temperatures reach pre-dam levels where the Gunnison enters the Colorado River, and the latter is not thermally affected by the Aspinall Unit (McAda 2003).

Backwaters

Development of towns such as Delta, the railroad that parallels the river downstream from Delta, and individual orchards and farms along the river led to the construction of dikes and bank protection measures all along the Gunnison River and to filling in or cutting off backwater areas. Irving and Burdick (1995) estimated that bottomland habitat availability was much more common prior to dike construction and flow regulation. The loss of backwaters may be of particular importance to the razorback sucker. The razorback spawns in the spring as flows increase and eggs hatch 1-2 weeks after spawning. Larvae are thought to drift into backwaters and floodplains that provide early critical habitat for the young fish. Backwaters were once extensive in the Delta area and have been reduced; this habitat has also been reduced downstream from the Roubideau confluence area but was probably never common. Flows above 10,000 cfs increase backwaters and flooded habitat. The frequency of years having flows greater than 10,000 cfs decreased from 57 % to 33 % following construction of the Aspinall Unit based on the period between 1937 and 1997. Similar channel modification developments occurred along the Colorado River, particularly in valley reaches.

Non-native species

Non-native fish have been introduced to the Gunnison and other basin rivers and now species such as the white sucker, common carp, red shiner, sand shiner, fathead minnow, and green sunfish are common in endangered fish habitat. Fifty-two fish species occur in the Upper Basin, but only 13 of those are native species (Fish and Wildlife Service 2000). Competition with and predation from the non-natives affect the endangered fish species. Tyus and Saunders (2001) discussed how competition and predation by introduced fishes has emerged as a major biotic factor limiting the survival and recovery of endangered fish populations. Overall, however, the Gunnison River appears to have a higher percentage of native fish (such as roundtail chubs and bluehead and flannelmouth suckers) than other upper basin rivers. The CDOW surveyed the Gunnison River in 2008 and reported a high

percentage of native fish with bluehead, roundtail, and flannelmouth common (Kowalski, 2008).

There is some belief that the Redlands Diversion may have impeded the spread of non-natives such as channel catfish and largemouth bass upstream into the Gunnison. Brown trout and to a lesser extent rainbow trout are common in the Gunnison River upstream from Austin and occasionally occur in critical habitat downstream from Delta. McAda (2003) reported that there is some evidence that high spring flows may reduce the abundance of some non-native fish. Burdick (2005) found that young of native fish composed a much higher percentage of the fish population in Gunnison River backwaters in the high water year of 1993 than in the low water year of 1992. The introduced species may be less able to survive the high flows than native fish. Even if this reduction is temporary, it may increase the survival of young native fish.

Non-native vegetation may also affect the fish. The non-native shrub tamarisk has become established along most of the Gunnison and Colorado rivers, facilitating stabilization of river banks.

4.4 Critical Habitat and Recovery Goals

Critical habitat for the Colorado pikeminnow and razorback sucker was designated in 1994. Overall 1,980 miles of rivers were designated. “Critical habitat," as defined in section 3(5)(A) of the ESA, means: ``(i) the specific areas within the geographical area occupied by the species at the time it is listed, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (III) specific areas outside the geographical area occupied by a species at the time it is listed, upon a determination by the Secretary that such areas are essential for the conservation of the species."

Designated critical habitat for the razorback sucker makes up about 49 % of the species’ original range and occurs in both the Upper and Lower Colorado River Basins. Critical habitat for the Colorado pikeminnow makes up about 29 % of the species’ original range and occurs exclusively in the Upper Colorado River Basin (FR 59 13374-13400). Critical habitat for both species includes the Gunnison River and its 100-year floodplain from the Uncompahgre River confluence to the Colorado River confluence (Figure 6). In Colorado and Utah critical habitat includes the Colorado River from the town of Rifle to Lake Powell; the Gunnison River from Delta to the Colorado River confluence; the Yampa River from Craig to the Green River; the White River from Rio Blanco Dam to the Green River; and the Green River from Dinosaur National Monument to the Colorado River confluence.

Critical habitat was also designated for all four endangered fish species within portions of the Colorado River in Colorado and Utah. Critical habitat for Colorado pikeminnow in Colorado extends from the town of Rifle to Lake Powell. Razorback sucker critical habitat extends from Rifle, Colorado to Westwater Canyon. Humpback chub and bonytail

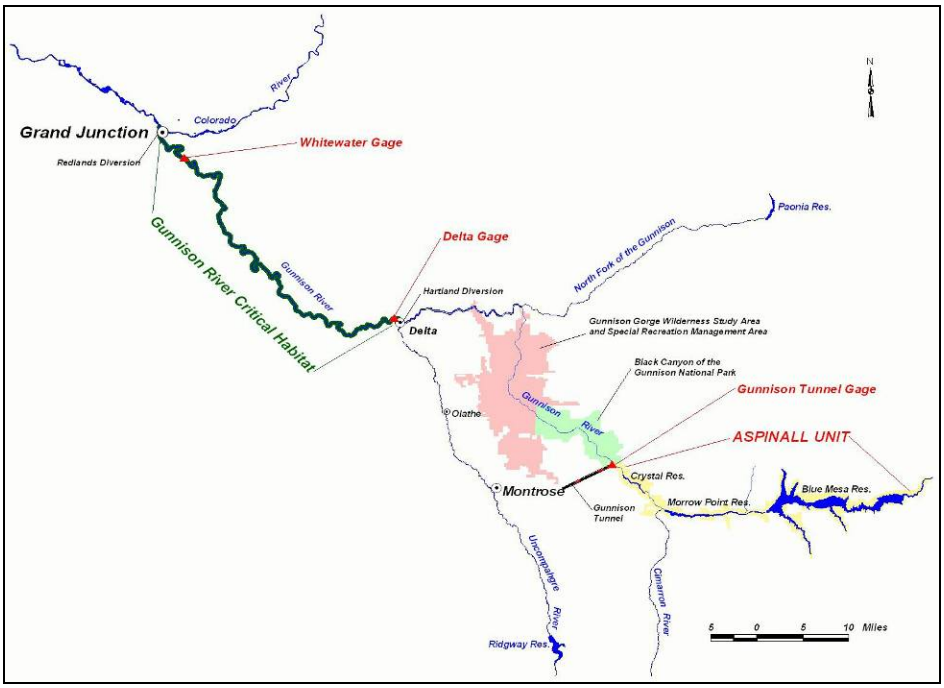


Figure 6. Critical habitat, Gunnison River.

critical habitat includes the Colorado River from Black Rocks to Fish Ford and Cataract Canyon in Utah.

Recovery goals, that define when species may be downlisted or delisted, were established for the species in 2002; these goals essentially call for establishing self sustaining populations. Goals are defined as population numbers, recruitment, and trends in the Green and Upper Colorado River. There are no specific goals for the Gunnison River, and Gunnison River populations would be included in the Upper Colorado River numbers. Recovery goal details are included in Attachment 7. At the present time, goals are being updated.

Recovery Goals for razorback sucker and Colorado pikeminnow recommend continued operation of the Redlands Fish Ladder and feasibility studies on increasing Gunnison River water temperature as site-specific management actions to address listing factors, and assessment of effects of selenium contamination are also identified for the entire Colorado River basin. The Recovery Program continues to fund and operate the Redlands Fish Ladder on an annual basis as part of its regular operation and maintenance budget. The Program also funded completion of two feasibility studies on potential modification of Aspinall Unit operations or infrastructure to increase water temperatures in the Gunnison River and expand endangered fish range, but have made no decision to date on the necessity of such actions for recovery.

4.5 Activities to benefit the species

The Recovery Program has overseen research activities on the endangered fish of the Gunnison River, with field studies being initiated in 1992. One end product of these investigations was publication of flow recommendations (McAda 2003) for the Gunnison and Colorado (downstream from the Gunnison confluence) rivers to benefit the endangered species.

The Aspinall Unit provided research flows during 1992-1998 for the Recovery Program studies, during which time release of excess water was reconfigured to provide a maximum release at Crystal Reservoir of 4,000 cfs. Duration and magnitude of releases varied greatly with inflow volumes. Since that time, Reclamation has implemented similar management of "risk of spill" water to benefit the endangered fish. The extended drought of the early 2000's has limited magnitude and duration of spring peaks, however. Studies completed during the research period included surveys of distribution and abundance of endangered fish in the Gunnison River (Burdick 1995); assessment of Gunnison River flows on Colorado pikeminnow larvae and nursery habitat in the Colorado (Anderson 1999; Trammell and Chart 1999a, b); changes in the geomorphology of the Colorado and Gunnison river channels (Pitlick et al. 1999); effects of research flows on young-of-year Colorado pikeminnow (McAda and Ryel 1999); response of endangered fish habitat to research flows (McAda and Fenton 1998); effects on humpback chub in Westwater Canyon (Chart and Lentsch 1999); and impacts of research flows on geomorphology and food web dynamics in the Colorado River (Lamarra 1999; Osmundson 1999; Pitlick and Cress 2000).

Results from the research period and other studies were utilized through a weight-of-evidence approach to develop the flow recommendations for the Colorado and Gunnison rivers (McAda 2003). Specific relationships between biological response and river flow were used to quantify the underlying causes for biological responses, with considerable emphasis on flow response of riverine habitats critical to endangered fish. Partial restoration of natural functions through mimicry of a natural hydrograph was hypothesized to benefit endangered fish and physical and biological resources they rely on (Stanford 1994; Stanford et al. 1996; Poff et al. 1997).

Control of non-native fish in the Colorado and Gunnison rivers began in 1995-1996, during which time small numbers of northern pike were removed from the Gunnison River with electrofishing, fyke nets and trammel nets (McAda 1997). The effort proved successful at suppressing northern pike range expansion in the Gunnison River due to low or nonexistent in-stream recruitment. More recently, increased numbers of smallmouth and largemouth bass in the Colorado River has prompted the Recovery Program to begin aggressive mechanical removal programs in the Grand Valley reach. While numbers of smallmouth bass have apparently declined following these efforts, numbers of largemouth bass have increased (Burdick and McAda 2007).

The Recovery Program has established hatchery and grow-out facilities, and stocking of Colorado pikeminnow and razorback sucker began in the Gunnison and Colorado Rivers in the 1990's in an effort to establish reproducing populations. A total of 49,954 razorback sucker (ranging from 100 to 300 mm in length) were stocked in the Upper Colorado (31,531) and Gunnison (18,423) rivers from April 1994 through October 2001 (Burdick 2003). Fish stocked at a minimum of 200 mm total length were recaptured most frequently. Larval fish monitoring indicates that these stocked razorback sucker are reproducing successfully.

Since 2001, 5,483-12,906 razorback sucker were stocked annually in the Colorado River and 549-3,805 were stocked in the Gunnison River (Tom Czapla, UWFWS, personal communication). The current stocking target for the Colorado and Gunnison rivers combined is 9,930, with the Colorado receiving about two-thirds of the fish. During that same period, stocked bonytail varied from 3,985 to 37,968 fish/year and the current target is 5,330 fish/year. Due to relative abundance of wild Colorado pikeminnow, stocking rates of this species are much lower (1,125 fish/year each in the Colorado and Gunnison rivers) and stocking occurred only in 2003 and 2004. To date, the Recovery Program has not determined the future of the Colorado pikeminnow stocking program.

Habitat improvements have been completed on the Gunnison River. A fish ladder was constructed around the Redlands Diversion and has been operated successfully since 1996; between 1996 and 2008 the ladder was used by 102 pikeminnow, 24 razorback suckers, 1 bonytail, and almost 86,000 other native fish (Recovery Program 2008). Recaptures have shown that there is some movement both upstream and downstream past the Redlands Diversion. A fish screen has been installed on the Redlands Canal to reduce losses of native and endangered species in the canal. Bottomland/floodplain habitat has been improved near Whitewater and Delta to increase nursery habitat for young fish. Fish passage, backwater protection, habitat improvement, and improved flows have also been implemented on the Colorado River mainstem. Growout ponds for razorback suckers have been constructed along the Gunnison River and are operated by the Service using water diverted from Gunnison River.

The Recovery Program has investigated the feasibility of warming releases from the Aspinall Unit (Hydrosphere 2002; Boyer and Cutler 2004). The two feasibility studies concluded that it was possible to meet downstream temperature targets for Colorado pikeminnow and razorback sucker (ca. 1-2 °C warmer than current conditions) through construction of a selective withdrawal structure on Blue Mesa Dam. However, uncertainties associated with model error, the status of the Gunnison River fish community and blockage of upstream migration routes at Hartland Diversion Dam prompted the Recovery Program to table discussions on construction of such a withdrawal structure until uncertainties are resolved.

A Coordinated Reservoir Operations Program (CRO; Recovery Program 2006a) was established through the Recovery Program to identify operational flexibility in existing water storage reservoirs that could collectively be used to enhance peak flows in the 15-Mile Reach of the Colorado River to benefit endangered fish species and their habitats

without reducing project yields, increasing costs or affecting a project's water rights. CRO participants requested official Recovery Program concurrence with the CRO concept and process, and the latter were approved by the Recovery Program Management Committee in 2006. Implementation of the CRO process has proven to be possible during most years since 1997. In 1998 and 1999, a total of 65,000 af was released to support spring flows, which on average increased spring peaks by 2,000 cfs. Apparently these contributions were sufficient to mobilize small proportions of the bed in the 15- and 18-mile (Gunnison confluence to Loma) reaches, and overall CRO can assist in providing flows to achieve sediment mass balance and avoid channel narrowing (Pitlick 2007).

Recovery Program activities in the Gunnison River are primary directed toward the Colorado pikeminnow and razorback sucker and no specific activities are designed for the humpback chub or bonytail. However, the two species are included in the flow recommendations (McAda 2003) which the Recovery Program has approved. These recommendations acknowledge the role of Gunnison River flows in the maintenance and improvement of habitat conditions in the Colorado River, where humpback chub and possibly bonytail are present. It is also possible that operation of the Redlands Fish Ladder may allow humpback chub or bonytail to occupy new habitat, and as noted previously bonytail have been stocked in Gunnison River backwaters.

5.0 OTHER SPECIES

5.1 Vegetation

5.1.1 Clay-loving wild buckwheat (*Eriogonum pelinophilum*)

The clay-loving wild buckwheat is a small shrub that is found in semi-desert shrub communities of adobe hills. It is normally located in specific microhabitats and can be associated with shadscale and mat saltbush. Its range is restricted to small acreages in Delta and Montrose Counties and primary threats include fragmentation or clearing of habitat for urban development and off-road vehicle use. In the early 20th century, habitat was probably more extensive and was probably cleared for agricultural lands. Soils supporting the species are derived from Mancos shale (Lyon and Williams 1998).

The species is not associated with riparian lands along the Gunnison River and would not be affected by the proposed operation changes. The buckwheat does occur in the vicinity of laterals and canals on the eastern side of the Uncompahgre Valley. This is the same area where selenium/salinity control improvements are a priority. Consequently, Reclamation will survey all selected work areas in order to identify and avoid disturbing populations of this species.

5.1.2 Uinta Basin hookless cactus (*Sclerocactus glaucus*)

The Uinta Basin Hookless Cactus is a small cactus normally found on gravelly alluvial soils or in clay between 4,500 and 6,000 feet and can be associated with shadscale, sagebrush, greasewood, saltbush, and other desert vegetation. In Colorado it is reported

from Montrose, Delta, Gunnison, Garfield, and Mesa Counties and is also found in Utah. Threats may include trampling from grazing, recreation use of lands, off-road vehicle use, and development on some lands. Past reports include populations on benches along the Gunnison River from Hotchkiss downstream (Lyon and Williams 1998). The species is not associated with riparian lands along the Gunnison River and would not be affected by the proposed action.

5.1.3 Jones' cycladenia (*Cycladenia humilis var. jonesii*)

The Jones' cycladenia is a small herbaceous perennial listed as threatened and restricted to the canyonland area of the Colorado Plateau in eastern Utah and a small portion of Arizona. This plant is found in gypsiferous soils in mixed shrub-pinon juniper communities. Threats include off-road activity and mineral development. The species is not associated with habitats that might be affected by the proposed action.

5.2 Wildlife

5.2.1 Western yellow-billed cuckoo (*Coccyzus americanus*)

The western yellow-billed cuckoo is a candidate for listing under the ESA. The species breeds in large blocks of riparian habitats, in particular cottonwood woodlands, and dense understory foliage appears to be important. Based on historical accounts, the species was localized and uncommon along Colorado drainages while being locally common in other western areas (Fish and Wildlife Service 2005). The species was probably never common in western Colorado and was considered extremely rare by Kingery (1998). In 1998, 242 miles of riparian habitat were surveyed along six rivers in west-central Colorado with only one cuckoo detected (Dexter 1998). In 2008 breeding of this species was confirmed along the North Fork of the Gunnison River; and cuckoos were observed during the breeding season at 6 locations near Hotchkiss and on 1 near Paonia (Beason 2008).

Cottonwood woodlands have been lost or fragmented in the study area due to clearing for towns and agriculture, filling and diking of lowlands, development of recreation sites in woodlands, fires, invasion of tamarisk and other non-native plants, and reduction of spring peaks that are important for regeneration of cottonwood stands.

Increased spring peaks with the proposed action may have some benefit to the regeneration of cottonwood stands which could provide habitat for the cuckoo; however, without long-term protection, cottonwood woodlands will continue to be degraded through other activities.

5.2.2 Mexican spotted owl (*Strix occidentalis lucida)*

The Mexican spotted owl is a threatened species and occurs in rocky canyons and forested mountains generally below 9,500 feet. The Mexican spotted owl has the largest geographic distribution of any of the *S. occidentalis* subspecies. Historically, the owl

ranged from the southern Rocky Mountains in Colorado; the Colorado Plateau in southern Utah; southward through Arizona, New Mexico, and far western Texas; in Mexico through the Sierra Madre Occidental and Oriental mountains and the southern end of the Mexican Plateau. Presently, the owl's range reflects the historic range, but owl numbers are much reduced and habitat is patchy. The primary threat Mexican Spotted Owls face is the loss of mature trees to timber harvesting and to stand-replacement fires, especially in steep canyons and in riparian zones. Several blocks of critical habitat have been designated in Colorado outside of the project area. Potential habitat for the species occurs in the project area; however, the proposed action would have no effect on this habitat.

5.2.3 California condor (*Gymnogyps californianus)*

The California condor is an extremely rare member of the vulture family. By 1982 only 22 condors existed and a captive breeding program began. The species was reintroduced to the Colorado Plateau in 1996 with the release of 6 birds in northern Arizona. Recovery goals include establishment of geographically separate populations in California and Arizona. Threats include lead poisoning, collisions with powerlines, and shooting. Released birds have made intermittent travels into the project area; however, there is no long-term use. Potential habitat for the species would not be affected by the proposed action.

5.2.4 Southwestern willow flycatcher (*Empidonax traillii extimus*)

The southwestern willow flycatcher nests in dense riparian vegetation and are thus vulnerable to impacts associated with modification of riparian habitats such as channelization, recreational development, grazing, and agricultural conversion (Kingery 1998). The subspecies does not occur in the Gunnison Basin but potential habitat occurs in the Dolores and Lower Colorado river basins. Critical habitat has not been proposed in the project area.

Increased spring peaks with the proposed action in the Colorado River may have some minor benefit to the regeneration of cottonwood and willow riparian stands which could provide habitat for the willow flycatcher; however, overall no effect is projected on this subspecies.

5.2.5 Black-footed ferret (*Mustela nigripes)*

The black-footed ferret is one of the most endangered mammals in North America. The ferret is associated with prairie dog towns and was once believed extinct. A reintroduction program is underway, including introductions in northwest Colorado. At the present time, there are no known populations in the Gunnison Basin. Potential habitat is fragmented in the basin, with prairie dog towns separated by cropland and other human developments. Historical presence in the basin is not known. The proposed action should have no effect on this species or its potential habitat.

5.2.6 Canada lynx (*Lynx canadensis*)

Lynx may have disappeared from Colorado by about 1973. Sightings prior to that time were few, scattered throughout mountainous areas of the state. In 1999 a program of lynx restoration began in the San Juan Mountains, and by 2005 more than 200 animals had been released, a number of litters of kittens had been born, and lynx were expanding throughout the high country and occasionally beyond. Lynx reproduction has not been confirmed in 2007 and 2008, possibly related to snowshoe hare declines. The lynx is found in dense sub-alpine forest and willow corridors along mountain streams and avalanche chutes, the home of its favored prey species, the snowshoe hare.

Reintroduced lynx have entered the Gunnison Basin where potential habitat occurs at higher elevations. The potential exists that the species will become permanently established in the basin.

The proposed action should have no effect on existing lynx populations or potential habitat.

5.2.7 Gunnison's prairie dog (*Cynomys gunnisoni*)

The Gunnison's prairie dog lives along the Colorado Plateau in southeastern Utah, southwestern Colorado, and portions of New Mexico and Arizona. Certain populations, including some in the Gunnison Basin, are considered as a candidate for listing under the ESA. Populations are considered to occur in two range portions – montane populations at higher elevations and prairie populations at lower elevations. The montane populations are considered as candidates for listing.

Habitat for the montane populations includes plateaus, benches, and intermountain valleys with grass-shrub-mountain meadow vegetation. There is an approximately 250 acre colony in the Curecanti Recreation Area at Blue Mesa Reservoir. Many factors influence populations including urban and agricultural development, other land conversions, grazing, poisoning, and recreational shooting; however, sylvatic plague is the most significant factor. This plague is a non-native pathogen that arrived in North America around 1900 (Seglund et al. 2005, Fish and Wildlife Service 2008).

The proposed action should have no effect on populations or habitat of this species.

5.2.8 Uncompahgre fritillary butterfly *(Boloria acrocnema)*

This butterfly is listed as endangered and has a very small known range in the mountainous areas of Gunnison, Hinsdale, and Chaffee counties of southwestern Colorado. All known colonies are associated with patches of snow willow above 12,500 foot elevation.

The proposed action should have no effect on populations or habitat of this species.

6.0 EFFECTS OF THE ACTION ON LISTED FISH

6.1 General

Water development and uses, along with other human activities; have probably been affecting the endangered fish species since the end of the 19th century. Early water uses greatly depleted base flows and water quality problems probably peaked early in the 20th century as new irrigation lands were developed, pollution from mining was high, and grazing and other land uses were largely unregulated (see Section 3.4.3 for more discussion).

6.2 Methodology

Existing information on potentially affected species was reviewed and appropriate information summarized for this report. Alternative Aspinall Unit operation modeling runs were conducted and reviewed with the Fish and Wildlife Service as part of informal Section 7 consultation on the effects of new operations on the endangered fish. During this consultation, peak flows, flow duration, flows downstream from the Redlands Diversion, and base flows were considered as well as concerns with factors such as potential flooding in the Delta area. Information on hydrology modeling is found in Section 3.4 and Attachment 12 and in the draft EIS for Aspinall reoperations.

Changes in habitat conditions, such as channel morphology and backwater availability related to flow changes, were then considered along with effects on water quality, non-native species, and other factors. Flows under the proposed alternative were also compared to the goals of the Flow Recommendations.
This section includes an analysis of the direct and indirect effects of the proposed action, its interrelated and interdependent activities on species and critical habitat. Cumulative effects are considered by assessing the effects of future actions reasonably likely to occur in the area.

While construction of the Aspinall Unit and other public and private water projects are not addressed in this PBA, the ongoing effects of operating the Aspinall Unit and other water uses are. In regard to endangered fish, these ongoing effects are reflected in the baseline and include habitat changes related to reducing spring peaks in critical habitat and increasing base flows, cooling summer water temperatures, and reducing concentrations of water pollutants by reservoir releases in low water periods.

The proposed action would have beneficial effects on the four listed Colorado River fishes and their critical habitat within the action area when compared to the baseline. Benefits result from the increased frequency, magnitude, and duration of spring peak flows and protection of base flows. The flow changes will assist in improving and maintaining habitat conditions for spawning and recruitment and for maintenance of adult pikeminnow and razorback sucker habitat. For Colorado pikeminnow (and probably other endangered fish), Osmundson and Burnham (1998) reported that the success of recovery efforts will largely depend on providing environmental conditions that increase

reproductive success and survival of early life stages. In general, the implementation of a flow regime that more closely resembles a natural flow regime of the river will provide benefits to the endangered fish and their habitat.

6.3 Flow and Habitat Effects

Table 11 and Figure 7 summarize a comparison of baseline and proposed action peak flows and Table 12 presents a comparison of the frequency of selected flows. Detailed information is contained in Attachment 8.1 and 8.2. It should be noted that mean daily peak flows are presented; instantaneous peaks would be higher. As discussed previously in this assessment, flows adequate to move sediment through the Gunnison River system are crucial to maintaining and improving critical habitat for the listed fishes. Reaching flows that are half bankfull or bankfull is considered key in the sediment movement. Goals of 8,070 and 14,350 cfs were established in the Flow Recommendations. At a flow of 8,070 cfs one-half (27) of the river cross sections identified by Pitlick et al. (1999) reach half bankfull (initial motion) and at 14,350 cfs one-half of the river cross sections reach bankfull (significant motion). As can be seen in Tables 12 and 13 and Attachment 8.4-8.5, the number of days that flow reaches these thresholds increases as well as the frequency of the years they are reached.

Table 11. Summary of peak flows (mean daily) at Whitewater gage for study period, baseline and proposed action.

	Baseline	Proposed action
Mean May peak flow (cfs)	8,551	10,124
Mean June-July peak flow (cfs)	7,448	8,310

Table 12. Percentage of years in study period when selected flow levels are exceeded at the Whitewater gage during the spring runoff. Half bankfull and bankfull highlighted.

Flow (cfs)	Percentage of years selected flow exceeded	
	Baseline	Proposed action
6,000	61	77
7,000	55	77
8,070	52	61
9,000	45	52
10,000	35	48
11,000	29	45
12,000	26	35
13,000	26	29
14,000	19	26
14,350	19	26

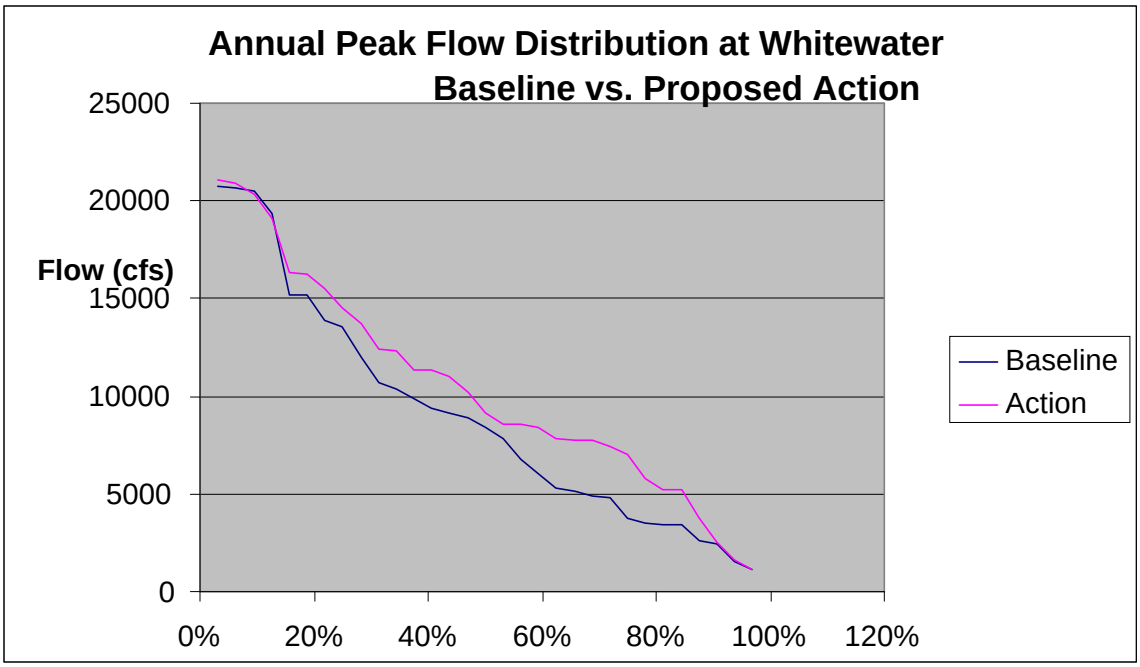


Figure 7. Expected frequencies of peak flows at Whitewater Gage under Baseline and proposed action conditions.

Under the proposed action, peak flows would be greater and occur more frequently than baseline peak flows. Proposed Action mean peak flows in May would be about 10,124 cfs, or 18% greater than the baseline peak (8,551 cfs). This average peak magnitude is more approximate of natural conditions, indicating a return to less regulated flow conditions. Peak flows equal to or greater than initial motion threshold flows (8,070 cfs; Pitlick et al. 1999) should occur during 19% more years under the proposed action than under the baseline, and flows equal to or greater than significant motion threshold flows (14,350 cfs) should occur during 33% more years than under baseline condition.

It should be noted that flows above and below target flows also provide benefits to habitat (Table 6 and Attachment 4). Table 13 shows the percentage of transects (Pitlick et al. 1999) where half bankfull and bankfull flow elevations were attained over a range of discharge and the relative gain in frequency of days at these flows under baseline and proposed action. The greatest gain (24%) occurs in average number of days at or above 10,000 cfs, at which time 80% of the transects are at half bankfull flow elevations. However, average number of days of flows at 6,000 and 7,000 also increases by 6% and 12%, at which level 20 to 35% of all transects are at half bankfull flows, indicating that finer bed materials are mobilized in many areas and gravel embededness is reduced.

Table 13. Percentage of study transects used by Pitlick et al. (1999) at which half bankfull and bankfull flows are attained at a given river flow and the average number of days (and % difference) each flow is met or exceeded within a given year under baseline flows and the proposed action.

	Pitlick transects		Duration of flow		
Flow (cfs)	% at half bankfull	% at bankfull	Days, under baseline	Days, under proposed action	% Difference
6,000	19	0	28.0	29.6	+6
7,000	33	0	21.6	24.2	+12
8,000	46	2	16.5	17.6	+7
10,000	81	6	8.8	10.9	+24
14,000	100	46	3.1	3.5	+13

Flows in the range of 4,400 to 5,300 cfs also have the capacity to mobilize sand and finer sediments, which should function to keep spawning substrates relatively clean (Pitlick et al. 2007). Frequency of years flows reach near bankfull elevations (14,350 cfs) is 33% greater under the proposed action than baseline conditions, with nearly half of all transects subject to significant (bankfull) bed load motion. Additional information on an annual basis is included in Attachment 8.3.

The increase in frequency and duration of initial and significant motion (half- and bankfull flows) under the proposed action would help maintain the interstitial spaces in gravel and cobble bars that provide spawning habitat, habitat for larval fish immediately after hatching, and for macroinvertebrates which are important for the food web of the endangered fish. Increases in significant motion conditions shift cobble and gravel bars, scour vegetation, and help maintain side channels which overall help maintain or improve channel complexity of benefit to the fish.

Flow regimes under the proposed action would result in increased interannual variability. In particular, during moderately dry years, spring releases would be made in proportion to inflow at Blue Mesa (381,000 to 516,000 af), which adds more certainty that the Gunnison River at Whitewater would vary between 2,600 to 8,070 cfs from one year to the next (Table 3). Similar proportionality would be seen during average wet years. In contrast, under baseline flows, such proportionality would be maintained only if excess water was available. Increased variability should support in-channel processes that help maintain habitat for the endangered fish, particularly during moderately dry years when half bankfull conditions could be attained at a greater percentage of river reaches than under baseline flows.

The potential relative difference in fine sediment movement when baseline flows and proposed action flows are compared can be seen in the differences in half and bankfull flows. More fine sediment would be mobilized under proposed action flows than under the baseline. Higher flows also have a disproportionate increase in sediment movement compared to lower flows. Thus, the net result of increased frequency of high flows would also include a greater active channel area under the proposed action.

The proposed action will meet the duration targets of the flow recommendations more frequently than baseline flows. Thus the proposed action more closely approximates recommendations for flow durations made by Pitlick et al. (1999; summarized in McAda 2003). The frequencies for which the two alternatives meet the half and bankfull maintenance and improvement flows is shown in Table 14. In most flow categories the proposed action consistently would provide more days at the described flows than the baseline flow. Thus the proposed action would more closely approximate recommendations.

Table 14. Frequency (% of recommended days for meeting or exceeding flow level) at which baseline flows and proposed action flows meet flow recommendations for half and bankfull flows for channel maintenance and improvement. Higher frequencies under the proposed action are highlighted in green.

	Baseline flows				Proposed action			
	Maintenance flows		Improvement flows		Maintenance flows		Improvement flows	
Category	% 1/2 bankfull	% bankfull	% 1/2 bankfull	% bankfull	% 1/2 bankfull	% bankfull	% 1/2 bankfull	% bankfull
Dry	na	na	Na	na	na	na	na	na
Mod. Dry	na	Na	0%	na	na	na	0	na
Avg. dry	126%	Na	84%	na	130%	na	87%	na
Avg wet.	50%	0%	40%	0%	100%	0	70%	0
Mod wet	84%	41%	56%	20%	91%	52%	60%	26
wet	109%	170%	66%	108%	112%	166%	67%	100

Due to operational limitations including flood control, extremely high flows (> 15,000 cfs) would not be significantly increased by the proposed action and thus flows that significantly modify channel conditions and create new habitat would not increase. These flows would probably occur in the future due to extreme hydrologic conditions or forecast errors but would not differ significantly from baseline conditions.

Floodplain and backwater habitat would be improved under the proposed action. Overall, inundation of floodplains tends to increase significantly between 5,000 cfs and 14,000 cfs, and frequency and duration of spring peak flows in this range are greater under the proposed action than under baseline flow conditions (Table 15). At 5,000-6,000 cfs small floodplain wetlands begin to be inundated in the area immediately downstream of Delta (Johnson Boys' Slough, others), and the Craig gravel pit pond near Whitewater connects to the main channel Gunnison River (Reclamation 2006b). Flooded acreage at the Escalante State Wildlife Area increases with Gunnison River flows such that 80, 140 and 200 acres become inundated at 8,000, 10,000 and 14,000 cfs, respectively (Valdez and Nelson 2006; Burdick and Irving 1995). Wetlands near Confluence Park at Delta flood at about 9,000 to 10,000 cfs. Additional information on an annual basis is found in Attachment 8.3.

Table 15. Floodplain flows-Baseline and Proposed Action for period of study.

	Days >5,000 cfs (Craig, Johnson Boys' Slough)		Days > 8,000 cfs (Escalante 80 acs)		Days >10,000 cfs (Escalante 100 acs, Confluence Park)		Days > 14,000 cfs (Escalante 200 acs)	
	Baseline	Action	Baseline	Action	Baseline	Action	Baseline	Action
Avg. days/yr	35.4	36.3	16.5	17.6	8.8	10.9	3.1	3.5
% of yrs	68	87	52	61	35	48	19	26

In most instances, the proposed action would assure flows to operate the Redlands Fish Ladder from April through September and the Redlands Fish Screen as needed. Migration flows of 300 cfs are recommended downstream from Redlands. Due to shifts in water release volumes toward the spring peak period, the proposed action would result in an average of 32.2 days annually below that flow level compared to 22.3 days under the baseline during April-September. Flows less than 100 cfs would increase by an average of 1.2 days annually during the same period under the proposed action (See Attachment 10).

Changes in the mainstem of the Colorado River have not been analyzed in detail for this assessment. In general spring flows would be increased in magnitude and/or duration downstream from the Gunnison confluence. The greatest increase would be seen in moderately wet and moderately dry years, during which over 1,500-2,000 cfs would be added to the flow of the Colorado River. About 2,000 cfs and 1,000 cfs would be added in average dry and average wet years. Dry and wet year additions would generally be negligible. In any case, benefits to the Colorado River due to increased flows from the Gunnison River would probably be maximized during years in which coordinated reservoir operations in the upper Colorado River basin are implemented. Since 2000, water – from releases from upstream Colorado River reservoirs, coordinated reservoir operations, and irrigation efficiency improvements -- averaging 48,000 af per year, has proved endangered fish habitat (Recovery Program 2008). Attachment 9 summarizes peak and average monthly flow changes for the study period below the Gunnison confluence and information is summarized in Table 16.

Table 16. Approximate average contribution of Gunnison River (cfs) to Colorado River during May spring peak during study period.

	Baseline Conditions	Proposed Action
Dry Year	2,072	2,120
Moderately Dry Year	4,229	6,864
Average Dry Year	7,807	10,445
Average Wet Year	11,048	13,028
Moderately Wet Year	12,354	15,070
Wet Year	19,052	19,053

This PBA assumes that similar beneficial effects of the proposed action on the Gunnison River ecosystem and endangered fish will be accrued to some extent in the Colorado River ecosystem. This assumption should be considered an uncertainty that should be evaluated by the Recovery Program.

Reclamation (Boyer 2004) developed a model to depict reservoir release water temperatures under the Flow Recommendations. This model showed that overall, release water temperatures would be similar under baseline and proposed action conditions. In years with increased spring flows, warming of the main channel of the Gunnison River would be delayed. If peak flows remain at or above 3,000 cfs during June, favorable Colorado pikeminnow spawning temperatures (≥18 °C) would occur in the Whitewater area but not likely in the Delta area (Figure 7). Favorable temperatures would occur in both areas during July at flows of about 2,000 to 3,000, however. The trade-off between high flows for channel maintenance and spawning temperature regime in the Gunnison River is thus an uncertainty that may need to be evaluated by the Recovery Program. The temperature of the Colorado River is not expected to change significantly in relation to the proposed action (McAda 2003).

There will be effects on water quality. The Aspinall Unit has tended to improve water quality conditions in critical habitat by reducing extremely low flow months when pollutants are concentrated. From August thru March, the Unit generally has more than doubled pre-Aspinall Unit flows. At lower flows, seen in some months under the proposed action, the dilution effects of Aspinall releases are reduced. However, base flows should be maintained adequately to provide dilution, and provision of base flows will reduce periods of extremely low flows. Operations will continue to eliminate periods of extreme low flows seen prior to construction of the Unit. Table 17 shows modeled information on average monthly flows at the Whitewater gage under the proposed action and Table 18 summarizes a comparison of average monthly flows for the baseline and proposed action. From a cumulative impact standpoint, ongoing projects in the basin to reduce salinity and selenium loading are expected to continue and this should help maintain or improve water quality

The proposed action will affect selenium levels in the Gunnison River. Under the Flow Recommendations, higher May and June flows will tend to increase dilution of pollutants in the river while lower flows in other months will tend to increase concentrations of pollutants. Increasing releases to meet base flows will tend to increase dilution of pollutants in moderately dry periods and thus maximum selenium levels should be reduced. Table 19 summarizes projected effects of the proposed action compared to baseline conditions and Table 20 compares baseline to proposed action with respect to number of days per year the state standard for selenium is exceeded at Whitewater. Figure 8 displays baseline and proposed action for average and maximum monthly selenium levels. More detailed information is found in Attachment 6.

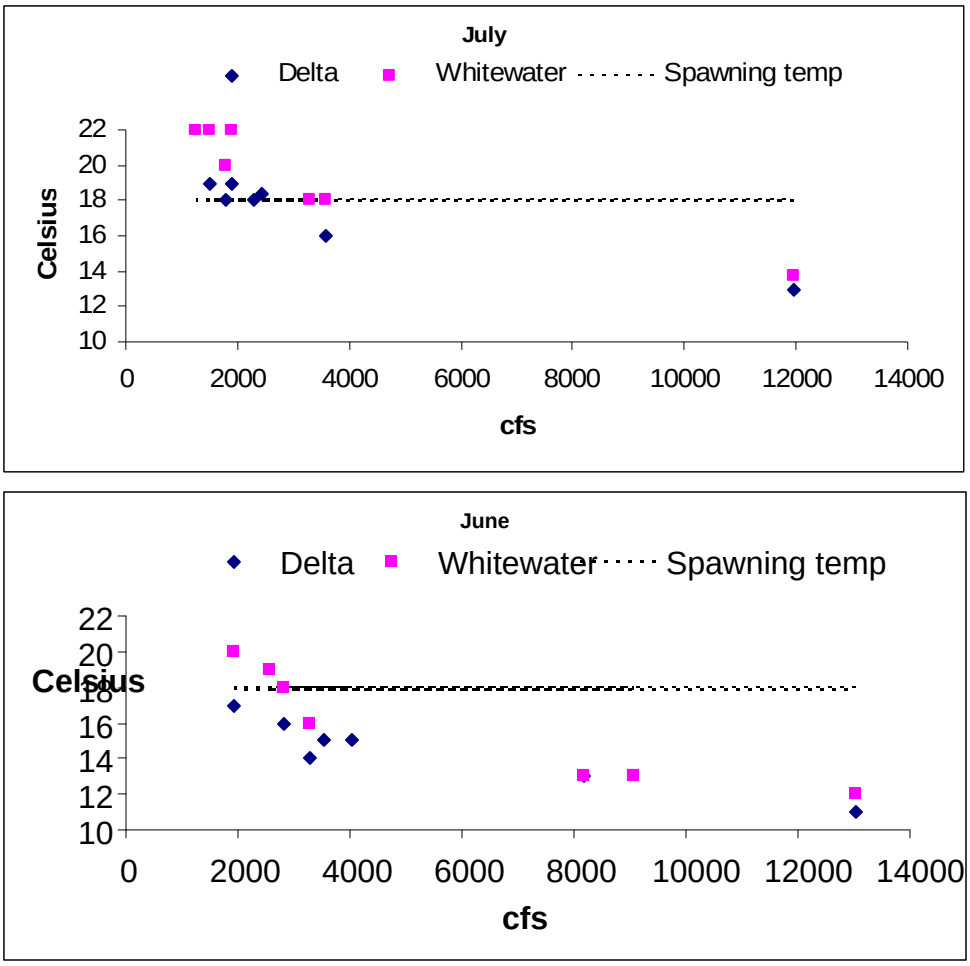


Figure 7. Gunnison River temperatures at Delta and Whitewater during June and July in relation to spawning temperature threshold for Colorado pikeminnow. Data were collected during 1992-2000 (McAda 2003).

6.4 Other Effects

The proposed action includes continuation of existing water uses and implementation of the Recovery Program and conservation measures. Existing water uses are included in the baseline and effects discussed include their continued operation. The continuation of the Recovery Program will support habitat restoration, monitoring, fish passage and screening, stocking, and better control of non-native fish. All of these actions are anticipated to have a positive effect on endangered fish populations.

Table 17. River flows (average monthly cfs), Gunnison River at Whitewater, for proposed action.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Peak daily mean
1975	1023	1022	1065	2422	6586	6328	3231	1929	1939	1866	1538	1489	12296
1976	1139	1189	1082	1620	5183	2293	1292	1025	1243	1395	905	807	8386
1977	789	767	757	785	846	879	939	794	795	902	873	778	1194
1978	764	748	858	3130	7000	7181	1696	1054	1162	1034	1098	1110	11364
1979	1046	2652	1906	4091	8976	9062	3043	1486	1207	1239	1163	1038	16261
1980	1033	2256	1576	3537	10244	7433	2319	1471	1286	1105	1190	1328	16326
1981	964	786	852	1304	1539	1423	1057	925	1179	1455	1082	826	3771
1982	1009	1144	1092	3277	7459	5157	2276	1938	2650	2604	2370	2299	11023
1983	1347	1277	1782	2797	8597	14045	7637	3031	2204	2445	2238	2531	17306
1984	2845	2629	2578	4918	13735	13699	6720	2774	2500	2997	2953	3179	19053
1985	2793	2241	2012	6587	10988	9986	2993	1608	2295	2680	2508	2600	15503
1986	2418	1655	3793	5421	8624	8032	3596	1947	2731	3335	3186	3250	13727
1987	1976	1795	2006	5171	6982	5710	1986	2032	2319	1809	1527	1516	10191
1988	1083	1196	1165	2267	2667	1849	1361	1046	1258	1030	901	818	5814
1989	851	1097	1614	2554	2508	1535	1331	1058	1117	1140	969	891	5243
1990	789	750	799	1006	1640	1584	1166	1014	1146	1352	962	883	2566
1991	813	781	864	1845	5278	4097	1904	1599	1994	1880	1630	1733	8593
1992	1124	1033	1138	3215	4130	2746	2073	1550	1631	1830	1565	1229	8583
1993	1050	1205	2843	4163	12387	10535	3747	2207	2345	2630	2215	1937	21040
1994	1328	1215	1489	2153	4503	2229	1550	1131	1409	1639	1428	1351	7755
1995	1044	963	2611	3348	9386	13708	12559	3024	2691	2767	2804	2729	19125
1996	1663	2156	2752	3485	7097	3507	1835	1342	1862	1781	1781	1856	12412
1997	2687	2716	2745	4364	9213	8632	3041	2405	3223	3177	2812	2716	14530
1998	1575	1461	2134	3578	7018	3129	2293	1519	1875	2038	1829	1718	9158
1999	1080	1085	1362	1374	4454	4381	2392	2576	2710	2352	2094	2043	7783
2000	1380	1393	1537	2719	3837	2190	1329	1066	1286	1417	1128	898	7840
2001	808	772	923	1487	4292	1711	1800	1323	1617	1496	1181	1112	7439
2002	969	823	840	1042	917	876	892	844	1094	1153	882	765	1170
2003	752	757	801	1181	3457	1825	1046	1060	1225	1020	858	770	7033
2004	779	765	1115	2038	2868	1313	1036	1060	1321	1304	980	889	5207
2005	943	898	1002	3958	7113	4503	2173	1435	1654	1923	1499	1186	11372
Mean study period	1286	1330	1584	2930	6114	5212	2655	1589	1773	1832	1618	1557	
Mean below average years	1017	1006	1175	1924	3573	2176	1494	1244	1448	1463	1212	1112	
Mean above average years	1576	1690	2041	4045	8959	8501	3924	1979	2138	2226	2059	2051	

Table 18. River flows (average monthly cfs), Gunnison River at Whitewater, for proposed action and baseline for study period.

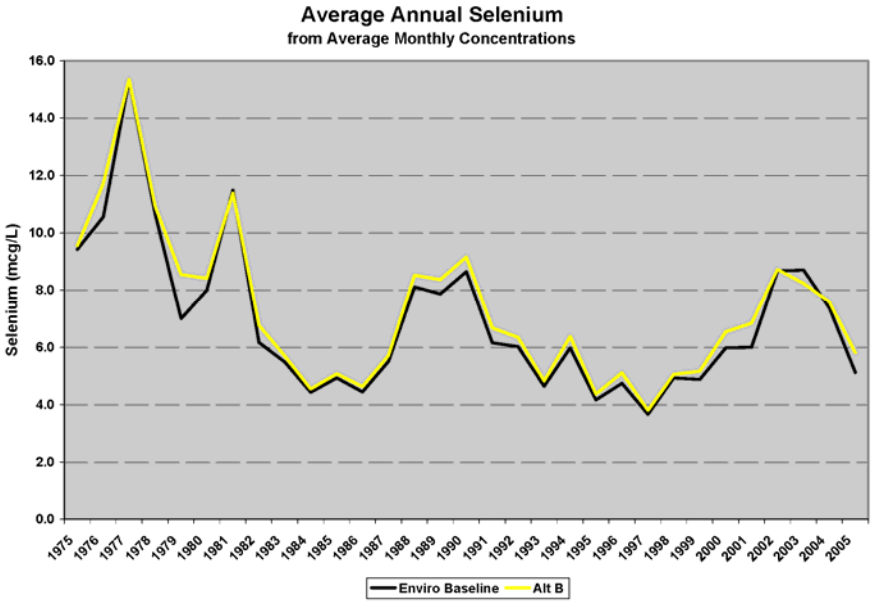
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1377	1408	1711	3122	5718	4993	2820	1641	1862	1895	1697	1650
Proposed Action	1286	1330	1584	2930	6114	5212	2655	1589	1773	1832	1618	1557

Table 19 Estimated selenium concentrations (mcg/L) at Whitewater gage under Baseline and under Proposed Action (proposed action shown in bold)

	Average annual concentration		Maximum monthly concentration		Minimum monthly concentration	
1975	9.5	**9.5**	16.8	**14.1**	3.6	**4.2**
1976	10.7	**11.7**	16.0	**17.3**	4.8	**4.1**
1977	15.4	**15.4**	18.9	**19.1**	12.0	**12.5**
1978	10.7	**10.9**	17.9	**15.5**	3.3	**3.3**
1979	7.0	**8.5**	10.4	**13.1**	2.6	**2.8**
1980	8.0	**8.4**	15.1	**14.3**	2.4	**2.4**
1981	11.5	**11.4**	17.2	**14.2**	7.4	**7.7**
1982	6.3	**6.8**	9.9	**10.9**	2.7	**2.7**
1983	5.5	**5.7**	7.9	**8.5**	2.1	**2.1**
1984	4.4	**4.5**	6.6	**6.8**	1.9	**1.9**
1985	4.9	**5.1**	8.3	**8.3**	2.0	**2.0**
1986	4.4	**4.6**	6.8	**7.1**	2.2	**2.2**
1987	5.5	**5.7**	8.1	**8.5**	2.4	**2.4**
1988	8.2	**8.5**	11.7	**12.2**	4.2	**4.4**
1989	7.9	**8.4**	11.0	**11.4**	3.9	**4.0**
1990	8.8	**9.2**	11.2	**11.2**	5.2	**5.4**
1991	6.3	**6.7**	9.3	**10.3**	2.8	**2.8**
1992	6.0	**6.3**	7.8	**8.2**	3.0	**3.0**
1993	4.7	**4.8**	8.3	**8.2**	1.6	**1.7**
1994	6.0	**6.4**	8.4	**9.1**	3.1	**2.9**
1995	4.2	**4.4**	7.7	**8.0**	1.6	**1.6**
1996	4.7	**5.1**	6.9	**7.8**	2.2	**2.1**
1997	3.7	**3.8**	5.1	**5.3**	1.8	**1.8**
1998	4.9	**5.1**	6.8	**7.0**	1.9	**2.0**
1999	4.9	**5.2**	7.2	**7.5**	2.8	**2.7**
2000	6.0	**6.5**	8.5	**9.5**	3.2	**3.1**
2001	6.1	**6.8**	7.7	**9.2**	3.1	**2.7**
2002	8.7	**8.7**	10.6	**10.7**	6.**0**	**6.4**
2003	8.6	**8.2**	11.7	**10.8**	3.5	**3.5**
2004	7.4	**7.6**	10.0	**9.7**	3.6	**3.4**
2005	5.3	**5.8**	7.8	**8.1**	1.8	**2.0**

Table 20. Number of days selenium concentration exceeds 4.6 ppb at Whitewater gage.

Year	Baseline	Proposed action
1975	311	325
1976	356	346
1977	365	365
1978	280	294
1979	275	276
1980	286	290
1981	363	363
1982	281	291
1983	254	256
1984	194	202
1985	233	257
1986	205	219
1987	259	261
1988	327	330
1989	320	316
1990	353	356
1991	289	295
1992	283	287
1993	225	225
1994	283	296
1995	169	176
1996	212	218
1997	68	106
1998	242	244
1999	242	263
2000	284	287
2001	301	319
2002	365	365
2003	326	327
2004	300	303
2005	229	266
Average	273.5	281.4



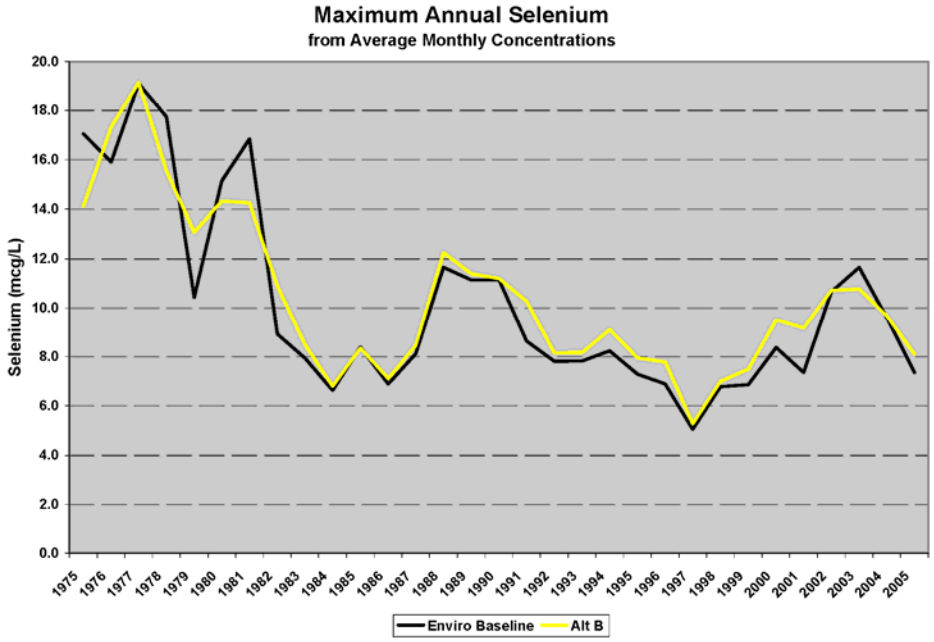


Figure 8. Selenium concentrations under baseline and proposed action, Whitewater gage.

6.5 Species Response to Proposed Action

As indicated in this assessment, there are a number of factors affecting the recovery of the endangered fish in the Gunnison River including reductions in habitat, competition with non-native fish, channelization, potential water quality concerns, and others. The proposed action does not resolve all of these factors but should improve conditions to increase recruitment and adult survival of the Colorado pikeminnow and razorback sucker in both the Gunnison and Colorado rivers and possibly the humpback in the Colorado River in conjunction with other Recovery Program actions. Response of the bonytail is unknown although the more natural hydrograph may have future benefits if populations are established.

In general, benefits of the proposed action include increased frequency and magnitude of relatively high spring flows to maintain channel conditions, spawning habitat, and channel complexity in critical habitat. The proposed flow regime should more closely resemble a natural flow regime when compared to baseline in that spring peaks would be greater in frequency, magnitude and duration, and that flows will vary among years in relation to snow pack and runoff. In addition to continuation of Recovery Program activities, the proposed action will provide benefits to the endangered fish and their habitat.

Species-specific effects of the proposed action are discussed below.

6.5.1 Colorado pikeminnow

6.5.1.1 Spawning

In all hydrologic categories, rising and falling hydrographs associated with the spring runoff from the North Fork and releases from the Aspinall Unit will provide environmental cues for Colorado pikeminnow spawning activity. Increased magnitude and duration of spring peak flows in the Gunnison River will maintain and improve spawning substrate by flushing fine sediment from the interstices of gravel and cobble substrates, which will improve survival of eggs and larvae. During moderately dry years, especially, increased frequency of peak flows between 2,600 and 8,070 cfs will improve spawning habitat even if widespread channel maintenance doesn’t take place. Flows in the range of 4,400 to 5,300 cfs are also beneficial because they have the capacity to mobilize sand and finer sediments, which should function to keep spawning substrates relatively clean (Pitlick et al. 2007). At higher flows (average dry through wet years), cleansing of gravel and cobble bars will be much more widespread and would maximize Colorado pikeminnow reproductive success. Enhanced river flows in the Colorado River should elicit a similar response there.

With increased frequency of high flows comes a greater probability of delayed warming of the Gunnison River. Since Colorado pikeminnow spawn on the descending limb of the hydrograph (ca. 15-30% of the peak or 1-4 weeks after the peak; McAda and Kaeding 1991; Trammell and Chart 1999a; Anderson 1999), they tend to spawn later (ca. early to

mid-July) during moderately wet and wet years and earlier during drier years (June; Figure 3.9 in McAda 2003). This adaptation is also related to the onset of favorable spawning temperatures (18-22 °C), which also occur later during wet years. Whereas spawning activity and hatching success should not be impeded directly by delayed warming, the growing season for offspring in wetter years is consequently shorter than during dry years. The effect may be partially offset due to greater connectivity with warm floodplain rearing habitats during wet years. Regardless, the trade-off facing Colorado pikeminnow between stream bed maintenance and temperature regime in the Gunnison River is an uncertainty that may need to be evaluated by the Recovery Program.

6.5.1.2 Larval and young-of-year habitat

As spring flows recede to base levels during the summer and fall, side channels and sandbar scour channels cease to flow and become backwaters. These are warm and productive environments which are important rearing habitat for larval and young-of-year Colorado pikeminnow. Under the proposed action, widespread maintenance of side channel and backwater habitats will occur at the half bankfull flow (8,070 cfs) in average dry to wet years, respectively. These flows would occur more frequently and with greater magnitude than those under baseline flows, helping to minimize vegetation encroachment, channel narrowing and vertical accretion of side-channel habitats. Cleansing of fine sediments from cobble bars and runs should also increase production of invertebrate prey items, on which juvenile stages of all endangered fish rely on for sustenance. Major changes in channel complexity will continue to depend on less frequent hydrologic events such as occurred in 1983, 1984 and 1993.

6.5.1.3 Adult habitat

The proposed action would help assure flows to operate the Redlands Fish Ladder from April through September and the Redlands Fish Screen. Due to shifts in water release volumes toward the spring peak period, the proposed action would result in an average of 32.2 days April through September below the migration minimum flow level compared to 22.3 days at baseline flows. Flows less than 100 cfs, which can significantly affect migration, would be increased by an average of 1.2 days under the proposed action (from 4.4 days to 3.2 days). Under both baseline and proposed action, most of the lower flows occur in very dry years, for example in 1977, 2002, and 2003 in the study period.

Higher and more frequent spring flows will provide more off-channel and floodplain habitat for feeding and resting of adult Colorado pikeminnow. These flows will also rework cobble bars, scour vegetation and help maintain overall channel complexity, the latter of which ensures a variety of habitats for Colorado pikeminnow feeding and resting throughout the course of a year. As mentioned above, also, flushing of fine sediments simultaneously prepares spawning habitat for Colorado pikeminnow and enhances primary and secondary productivity.

6.5.1.4 Non-native fish

Young-of-year Colorado pikeminnow share backwater rearing habitat with a host of non-native fish dominated by fathead minnow, sand shiner and red shiner. McAda and Ryel (1999) demonstrated that abundance of non-native cyprinid species during both summer (larvae) and autumn (juvenile and adults) was inversely correlated with magnitude of the previous spring peak flows, whereas relationship of young-of-year native fish to spring peak flows was either positive or statistically not significant. Thus, increased frequency and magnitude of spring peaks under the proposed action would disadvantage competitive and/or predatory non-native fish while not harming young-of-year native fish. Operation of the selective Redlands Fish Ladder would continue to prevent upstream migration of non-native fish into the Gunnison River.

6.5.1.5 Floodplain connectivity

In contrast with razorback sucker, Colorado pikeminnow reproduction is not as dependent on presence of floodplain wetlands for enhanced larval survival and growth. However, higher and more frequent spring flows will provide more off-channel and floodplain habitat for feeding and resting of adult Colorado pikeminnow prior to spawning, perhaps contributing to overall reproductive fitness.

6.5.1.6 Water quality

While flows in non-peak months will be reduced, base flows should remain adequate to continue to provide dilution flows and protect water quality (Tables 17-20). Other programs, such as salinity and selenium control programs, to protect/improve water quality will continue and will be supplemented by conservation measures associated with the proposed action and are expected to promote gradual improvements in water quality in the action area.

6.5.2 Razorback sucker

6.5.2.1 Spawning

Effects of the proposed action on razorback sucker spawning habitat would be very similar to those described for Colorado pikeminnow (Section 6.5.1.1). Since razorback sucker can spawn over a lower and wider range of temperatures (8-19 °C), delayed warming would probably not affect their larval growth and survival as much as it would Colorado pikeminnow.

6.5.2.2 Larval and young-of-year habitat

Effects of the proposed action on razorback sucker rearing habitat would be very similar to those described for Colorado pikeminnow (Section 6.5.1.2). Since razorback sucker rearing is thought to be more strongly associated off-channel floodplain wetlands, effects on those habitats are likely more important for razorbacks.

6.5.2.3 Adult Habitat

Effects of the proposed action on razorback sucker adult habitat would be very similar to those described for Colorado pikeminnow (Section 6.5.1.3). Like Colorado pikeminnow, adult razorback sucker utilize a variety of habitats throughout the course of the year and prefer complex river segments; thus, higher and more frequent spring peaks would work to maintain and perhaps improve channel complexity by mobilizing sediment, scouring vegetation and reducing accretion.

6.5.2.4 Non-native fish

Effects of the proposed action on non-native fish would be very similar to those described for Colorado pikeminnow (Section 6.5.1.4).

6.5.2.5 Floodplain connectivity

Razorback sucker spawning is timed to coincide with availability of inundated floodplains that provide warm, productive environments for larvae. Transport of larval fish into floodplains appears to be an important factor in determining recruitment of razorback sucker. In the Gunnison River, connection to important floodplain rearing habitats (Craig, Escalante, Confluence Park, and Johnson Boys' Slough) during the spring peak will be made under the proposed action more frequently and for longer durations than under baseline flows. The increase in duration of connection within a year is particularly important because a wider window of opportunity is open to drifting larvae for entrainment into productive rearing habitats. Additionally, the increased duration of flooding represents an opportunity for increased growth, since even short periods of inundation can provide the warm, food-rich habitat required for high survival of larvae (McAda 2003). This increased growth can be particularly important if size-dependent processes such as predation by small, gape-limited predators (e.g., red shiner) are important regulators of survival.

High flow connections (ca >14,000 cfs) to Escalante SWA are significant as they allow access to a 200 acre oxbow wetland, one of five tracts in the largest wetland complex in the Gunnison corridor. Both Colorado pikeminnow and razorback sucker are suspected to use these wetlands on a seasonal basis (Valdez and Nelson 2006). The connection to Craig is also significant as it has been recommended to receive stocking of hatchery-reared razorback sucker and could very likely entrain wild-spawned drifting larvae (Valdez and Nelson 2006).

6 .5.2.6 Water quality

Effects of the proposed action on water quality would be very similar to those described for Colorado pikeminnow (Section 6.5.1.6).

6.5.3 Humpback chub and bonytail

Benefits of the proposed action for humpback chub in the Colorado River would include most of what has been described for Colorado pikeminnow and razorback sucker, including:

- Spawning cues due to spring peak flows
- Maintenance of habitat complexity over a range of flows
- Maintenance of spawning gravel
- Creation and maintenance of backwaters
- Reduction of non-native fish due to higher flows

Attachment 9 summarizes expected changes in the Colorado River due to the proposed action.

Because of its extreme rarity, response of bonytail to the proposed action may be difficult to quantify. However, since all four endangered fish evolved together in the Colorado River ecosystem and the flow recommendations were based on common river restoration practices and habitat needs of the more common endangered species, bonytail should benefit from the proposed action as well.

6.6 Cumulative Effects

In the Service's regulations at 50 CFR 402.02, cumulative effects are defined as those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area of the federal action subject to consultation. To the best of Reclamation's knowledge, there are no proposed, authorized or permitted water development projects or activities foreseen at the present time that have not been defined as part of the action. Therefore, despite Reclamation's finding that there may be adverse effects of listed species, state or private cumulative impacts are not projected.

6.7 Uncertainties and Take

Uncertainties discussed in the flow recommendations or related to the proposed action include:

- While relationships among initial motion, significant motion and streamflow are well defined, duration of flows necessary to accomplish habitat work is not completely known. Because flow duration recommendations were developed

based on a wet period, the recommended durations require a large volume of water that may not always be available.

- Water availability may limit the ability of the Gunnison River to meet the Flow Recommendations under certain conditions.
- "…the duration of flows necessary to accomplish in-channel and out-of-channel habitat maintenance objectives is not known."[1]
- Because of timing and other differences in runoff patterns of the Colorado and Gunnison rivers, it is difficult to predict the effect of Gunnison River flow changes on the Colorado River.
- The trade-off facing Colorado pikeminnow between stream bed maintenance and temperature regime in the Gunnison River is an uncertainty that may need to be evaluated by the Recovery Program.
- The Recovery Program may need to evaluate the trade-off between high spring flows and base flows needed during the mid- to late summer to operate Redlands (and, to a lesser extent perhaps, maintain movement of sediment through the system).
- The effect of selenium and other water quality elements on the recovery of the endangered fish in the Gunnison and Colorado rivers and other basin rivers is not known and further monitoring by the Recovery Program may be needed.

For these reasons, the proposed action calls for using adaptive management (Section 2.2) to respond to new knowledge and using monitoring to evaluate the physical response of the habitat and biological response of the fish to the flow regimes.

Section 9 of the Endangered Species Act addresses "take". Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Take was considered in terms of continued diversions of water in critical habitat and in new and continued water depletions.

Incidental take associated with existing water diversions in Gunnison River critical habitat is difficult to assess but should not be significant. A previous biological opinion has addressed take for the Redlands Diversion, the only major diversion in critical habitat (Fish and Wildlife Service 2004). The other diversions in critical habitat are pumps or instream diversions for individual farms/orchards or small groups of users. These small diversions should pose little threat to adult and subadult fish. As fish recover and spawning increases in the Gunnison River, some loss of larval fish would be expected at these diversions; however because diversions generally divert well less than one percent of the river flow, losses should not be significant.

[1] Research under the Recovery Program is ongoing in the Gunnison River. Under one sediment-monitoring project the primary objective "…is to address key uncertainties in priority reaches of the Colorado, Gunnison, and Green Rivers relevant to the role of streamflows and sediment transport on the formation and maintenance of backwater habitats and spawning bars. A secondary objective is to collect the necessary sediment data to aide in the evaluation of Service flow recommendations for the Aspinall Unit and Flaming Gorge Reservoir." (Fish and Wildlife Service 2006).

Continued and new depletions associated with the proposed action are considered an adverse effect and are intended to be offset by new operations. New depletions can affect habitat and reproduction/recruitment; however, estimating the number of individuals of these species that would be taken as a result of water depletions is difficult to quantify.

The number of larvae that may be incidentally taken as a result of any of these factors is unknown. However, because of the potential for loss of individual listed species in fish screens and diversions, Reclamation requests an incidental take statement.

Another form of take might be associated with foregone growth potential due to higher frequency of high flows and potentially lower water temperatures and also perhaps the trade-off of moving water into the peak season at the expense of flows later in the year.

7.0 CONCLUSIONS

Based on the information and analysis of effects in this PBA, the following determinations were made for each of the listed species in the action area.

Clay-loving wild buckwheat	*Eriogonum pelinophilum*	no effect
Uinta Basin hookless cactus	*Sclerocactus glaucus*	no effect
Jones' cycladenia	*Cycladenia humilis var. jonesii*	no effect
Yellow-billed cuckoo	*Coccyzus americanus*	no effect
Mexican spotted owl	*Strix occidentalis lucida*	no effect
Southwestern willow flycatche r	*Empidonax traillii extimus*	no effect
California condor	*Gymnogyps californianus*	no effect
Colorado pikeminnow	*Ptychocheilus lucius*	may affect, likely to adversely affect
Razorback sucker	*Xyrauchen texanus*	may affect, likely to adversely affect
Humpback chub	*Gila lacypha*	may affect, likely to adversely affect
Bonytai	*Gila elegans*	may affect, likely to adversely affect
Black-footed ferret	*Mustela nigripes*	no effect
Canada lynx	*Lynx Canadensis*	no effect
Gunnison's prairie dog	*Cynomys gunnisoni*	no effect
Uncompahgre fritillary butterfly	*Boloria acrocnema*	no effect

When compared to the environmental baseline, the proposed action will have overall beneficial effects on the razorback sucker and Colorado pikeminnow and their critical habitat and may benefit the bonytail and humpback downstream in the Colorado River. The new operations of the Unit along with future Recovery Program efforts and conservation measures will improve designated critical habitat conditions for the fish as compared to baseline conditions. However, there is a potential for take under both the baseline and under the proposal. This potential take from entrainment in canals and depletions could result in the harm or kill of individual endangered fish in the Gunnison or Colorado rivers. Therefore, due to the potential for take, the finding is that the proposed action may affect, is likely to adversely affect endangered fish species.

Other species considered in this PBA should not be affected by the proposed action.

8.0 REFERENCES CITED

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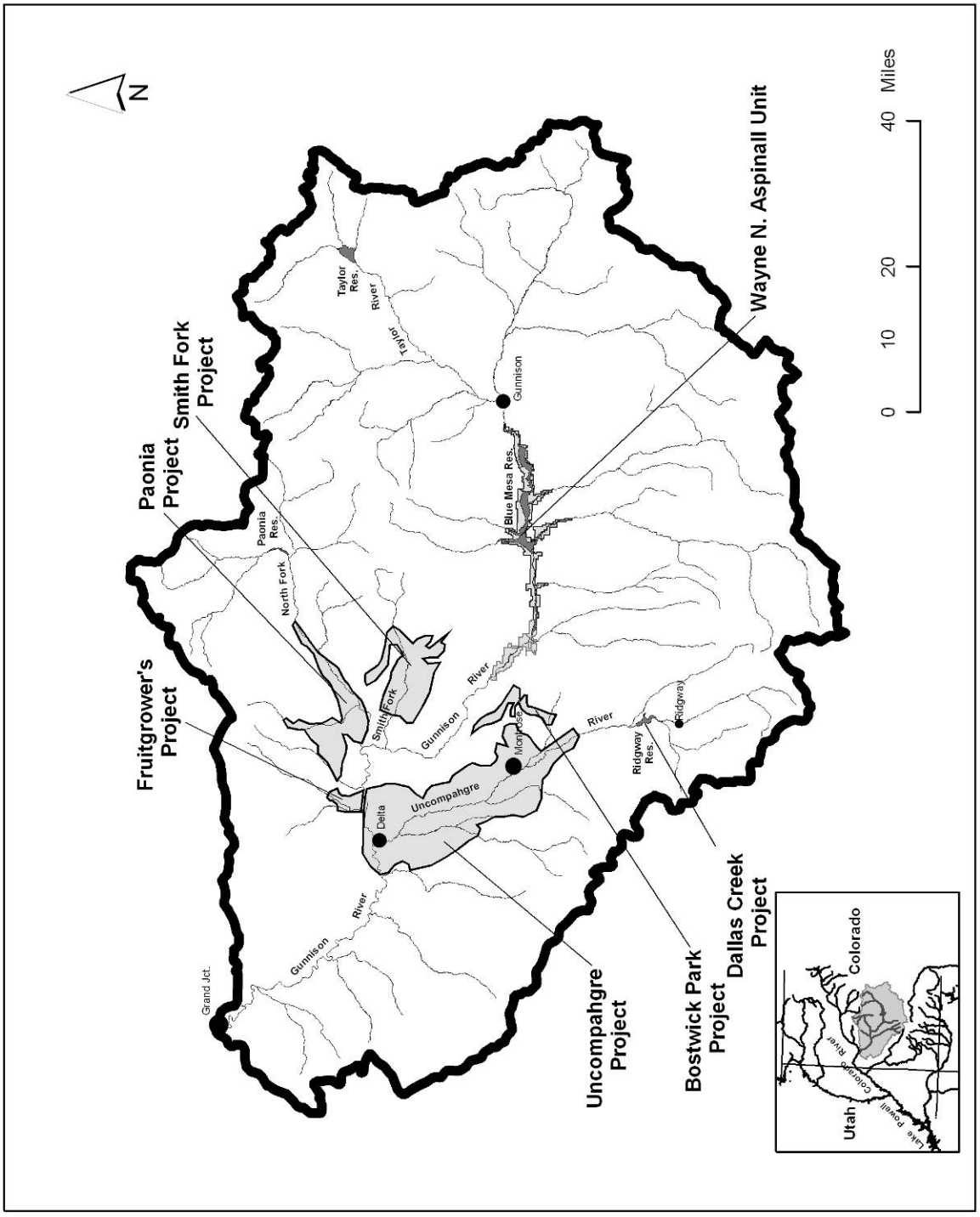
Attachment 1--Description of Gunnison Basin Reclamation Projects



DESCRIPTION OF OTHER RECLAMATION PROJECTS IN THE GUNNISON RIVER BASIN

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Bostwick Park Project

General Description
The Bostwick Park Project is in west-central Colorado near the city of Montrose. The project develops flows of Cimarron Creek, a tributary of the Gunnison River, for irrigation and for benefits to sport fishing and recreation. A full and supplemental supply of irrigation water is available for 6,100 acres of land. Recreation opportunities and important fishery benefits are provided at Silver Jack Reservoir.

Unit descriptions and facilities
Water storage is provided by Silver Jack Dam and Reservoir, constructed on Cimarron Creek. Project water is released from the reservoir to Cimarron Creek. The releases, along with usable natural flows, are diverted from the creek into the existing Cimarron Canal 2.5 miles below the dam, and conveyed 23 miles to the vicinity of the project land. Some water is released from the canal and used on lands in the Cimarron area. Most of the water is conveyed to the end of the canal at Cerro Summit and then delivered to the Hairpin and Vernal Mesa Ditches. The project-constructed Bostwick Lateral diverts water from the Vernal Mesa Ditch and conveys it across Bostwick Park through an 18-inch siphon to lands above the West Vernal Mesa Lateral.

Silver Jack Dam Silver Jack Dam is located on Cimarron Creek about 20 miles above the junction with the Gunnison River. The rolled-earthfill dam contains 1,278,140 cubic yards of material and has a structural height of 173 feet. Its crest is 1,050 feet long and 30 feet wide. The outlet works to Cimarron Creek in the right abutment has a capacity of 280 cubic feet per second with the reservoir at the normal water surface elevation of 8926.0 feet and a capacity of 160 cubic feet per second at the minimum water surface elevation of 8840.0 feet. The spillway on the right abutment is an uncontrolled ogee section with a capacity of 6,220 cubic feet per second at maximum water surface elevation. The reservoir has a total capacity of 13,520 acre-feet, including 12,820 acre-feet of active capacity and 700 acre-feet of inactive capacity. When filled to its normal water surface elevation, the reservoir has a surface area of 293 acres.

The 3.6-mile Bostwick Lateral was constructed to deliver water to full service lands above the West Vernal Mesa Lateral. Repair, extension, and some new construction of about 7.2 miles of drains were completed by the water users.

Operating agencies
Project irrigation facilities were turned over to the Bostwick Park Water Conservancy District for operation and maintenance on January 1, 1976.

Development History
The Bostwick Park area was settled in the early 1880's, followed by a second influx at the time of irrigation development in 1910. By 1930, the population had reached a peak of 75 to 80 families, but in 1960 decreased to about 40

families because of the trend toward larger farm units, use of modern labor-saving farm equipment, and drought conditions.

Investigations
The Bureau of Reclamation first reported on the Bostwick Park Project in a 1951 reconnaissance report on the Gunnison River Project. The plan presented in the 1961 feasibility study, upon which authorization was based, was essentially the same as the 1951 plan.

Authorization
The project was authorized as a participating project of the Colorado River Storage Project by Public Law 88-568, September 2, 1964 (78 Stat. 852). The primary purposes of the project are agriculture, recreation, and fish and wildlife.

Construction
Construction began at Silver Jack Dam late in 1966 and was completed in 1971. Silver Jack Reservoir was filled on June 10, 1971, and project water was available to supplemental service lands from existing ditches on a water rental basis during the 1971, 1972, and 1973 irrigation seasons. A negative declaration of environmental impact was filed July 21, 1972, for drainage rehabilitation and for replacement of the Vernal Mesa conduit. Construction of these facilities was completed during fiscal year 1974.

Benefits

Irrigation
The project furnishes a dependable late-season supply of irrigation water. Non-project supplies are generally abundant until the latter part of the irrigation season, but then fall off resulting in serious curtailment of crop yields. Project water from Cimarron Creek, and in small part from tributaries of Cedar Creek, is used as a full irrigation supply for lands not previously irrigated and as a supplemental supply for lands inadequately served.
Raising beef cattle and sheep are the major enterprises in the project area. Irrigated lands are used chiefly for the production of alfalfa, grass hay pasture, and small grains for livestock feed.

Recreation and Fish and Wildlife
The U.S. Forest Service developed recreation facilities under a cooperative arrangement with the Bureau of Reclamation. Facilities include access roads, campgrounds, a boat dock, trails, fences, landscaping, and an administration site. There were 84,500 visitor days to the reservoir area in 1996.

Flood Control
Bostwick Park Project has provided an accumulated $34,000 in flood control benefits from 1950 to 1999.

Dallas Creek Project

General Description
The Dallas Creek Project is located in west-central Colorado near the town of Ridgway. It is named after the Dallas Creek tributary of the Uncompahgre River, which in turn is a tributary of the Gunnison River in the Upper Colorado River Basin. The project area includes most of the Uncompahgre River Basin covering portions of Montrose, Delta, and Ouray Counties.

Unit descriptions and facilities
Ridgway Dam of the Dallas Creek Project was constructed on the Uncompahgre River in 1987 to increase water supplies for irrigation and municipal and industrial purposes, and to provide flood control. The project also includes recreational development at the reservoir and measures to enhance fishing opportunities on the Uncompahgre River, improve wildlife habitat, and mitigate wildlife losses caused by the reservoir development. No distribution facilities were constructed as part of the project. Water supplies are distributed through existing facilities or facilities constructed by the Tri-County Water Conservancy District or the water users.

Ridgway Reservoir is formed by Ridgway Dam on the Uncompahgre River about 6 miles north of Ridgway, Colorado, and 1 mile upstream from the confluence with Cow Creek. The reservoir has a capacity of 84,410 acre-feet of water and extends southwardly up the Uncompahgre River for 4.6 miles, with a 1-mile branch up the drainage of Alkali Creek. Active storage capacity is 59,396 acre-feet; dead and inactive capacity is 25,000 acre-feet. The surface area of the reservoir at the normal water surface elevation of 6,871.13 feet is 1,030 acres. Ridgway Dam is a rolled earthfill structure with a volume of 10,900,000 cubic yards and a height of 234 feet above streambed. The dam crest, at elevation 6886, is 2,460 feet long and 30 feet wide.

Operating agencies
The Tri-County Water Conservancy District is the general administrative agency for the project and is the contracting and marketing agency for all project water.

Development History
When the Ute Indians were moved to reservations in 1881, a rush of settlers poured into the Uncompahgre Valley attracted by new farming and ranching opportunities. The town of Delta was founded that year, followed by Montrose in 1882, Olathe in 1883, and Ridgway in 1890. Irrigated agriculture expanded rapidly throughout the valley with the construction of small, privately financed diversion structures. Restrictions imposed by private financing limited these developments to lands close to the streams.
In 1912, the Uncompahgre Project, one of the first Federal reclamation developments, began delivering water from the Gunnison River through the Gunnison Tunnel to lands around Montrose, Olathe, and Delta. After the successful irrigation of lands in the lower Uncompahgre Valley, interest developed in constructing a water delivery system for

potential farmlands on Log Hill Mesa, south of Ridgway, and along the upper Uncompahgre River and its tributaries.

Investigations

Soon after World War II, the Bureau of Reclamation began to study the possibility of a water project for the upper Uncompahgre River Basin. Early planning was directed toward irrigation. One of the first plans, called the Ouray Project, was never formally published, but it was the starting point for ensuing years of study. In February 1951, Reclamation published a reconnaissance report on the Gunnison River Project. One part of this extensive project was the Dallas Creek Unit, which included many of the features of the Ouray Project. After publication of the 1951 report, Reclamation studied a number of alternative plans. A plan to produce hydroelectric power in addition to irrigation power generation would not have interfered with irrigation proposals being considered, so it was added to the 1951 reconnaissance plan. Investigation of a dam site in Ironton Park indicated that it was not a geologically satisfactory site. This fact and the possibility of a conflict over water rights caused the proposal to be dropped from consideration.

The cost of the project, to eventually be repaid, was a problem for proposed irrigation developments in high elevation valleys like the upper Uncompahgre Basin because the cash value of crops produced per acre was comparatively low. This problem was largely alleviated for Dallas Creek in 1956 when the Congress passed the Colorado River Storage Project (CRSP) Act. One of the features of this act was to provide money from power revenues from CRSP facilities to assist designated participating irrigation projects in their repayment. The Dallas Creek Project was designated as one of these participating projects and was given priority for feasibility studies and financial assistance if authorized by the Congress.

After designation as a CRSP participating project, concentrated feasibility investigations were made of the project, which became a refinement of the 1951 reconnaissance plan, and published in a 1966 feasibility report. Municipal water was included in the plan for the first time. This plan was the basis for congressional authorization of the project in 1968. A definite plan report, published in November 1976, presents results of studies made since the project was authorized and outlines revisions of the project plan brought about by changing conditions. The final environmental impact statement was filed with the Council on Environmental Quality in September 1976 after a public hearing on the draft statement in Montrose, Colorado, on April 17, 1976.

Authorization

The Dallas Creek Project was authorized by the Colorado River Basin Act of September 30, 1968 (Public Law 90-537), as a participating project under the Colorado River Storage Project Act of April 11, 1956 (Public Law 84-485), based on the feasibility report of the Secretary of Interior transmitted to the Congress on May 3, 1966, and published as House Document 433, 89th Congress, 2nd Session. The project was constructed for municipal, industrial, agricultural, recreation, flood control, and fish and wildlife purposes.

Construction
Construction started in 1978, was completed in 1987, and Ridgway Reservoir first filled in 1990.

Benefits

Irrigation
Production of livestock, predominantly cattle and sheep, is the leading enterprise in the area. Crops consist primarily of livestock feeds such as alfalfa, meadow hay, pasture, and small grains. Irrigated lands in the area also produce pinto beans, malt barley, shelling and ensilage corn, alfalfa, onions, and some fruit. Project water supply for irrigation purposes totals 11,200 acre-feet, the largest portion of which is supplemental supplies for the Uncompahgre Project.

Domestic, Municipal, and Industrial
A water supply of 28,100 acre-feet is available for municipal and industrial uses in Colona, Montrose, Olathe, Delta, and surrounding rural areas.

Recreation and Fish and Wildlife
Recreational development includes facilities for picnicking, camping, boating, hiking, and enjoyment of the scenic setting. Measures to protect and enhance the fish and wildlife resources have been incorporated into the project plans. They include minimum flows in Uncompahgre River, a deer fence along a relocated highway, and acquisition of a wildlife range to offset losses associated with the reservoir. The Ridgway Recreation Area is administered by Colorado State Parks In 1996, visitation totaled 629,298.

Flood Control
Ridgway Reservoir is operated to aid in controlling snowmelt floods. Reservoir storage is evacuated to provide space for flood flows if heavy snowmelt is predicted. Although the reservoir is not operated specifically for control of rain floods, it aids in control as storage space is available in the reservoir in late summer when such floods normally occur. From 1950 to 1999, Dallas Creek Project had $53,000 in accumulated actual flood control benefits.

Dolores Project

General Description
The Dolores Project, located in the Dolores and San Juan River Basins in southwestern Colorado, uses water from the Dolores River for irrigation, municipal and industrial use, recreation, fish and wildlife, and production of hydroelectric power. It also provides flood control and aids in economic redevelopment. Service is provided to the northwest Dove Creek area, central Montezuma Valley area, and south to the Towaoc area on the Ute Mountain Ute Indian Reservation. A full and supplemental supply of irrigation water is available for 61,660 acres.

Unit descriptions and facilities

Primary storage of Dolores River flows for all project purposes is provided by McPhee Reservoir, formed by McPhee Dam and Great Cut Dike. Dawson Draw Reservoir, located west of McPhee Reservoir, was constructed specifically for fish and wildlife enhancement and is supplied primarily from irrigation return flows.

An average annual supply of 90,900 acre-feet of water is provided to 27,860 acres of full service land in Dove Creek, 7,500 acres of full service land in Towaoc, and 26,300 acres of supplemental service land in Montezuma Valley. Water for the Dove Creek area is pumped from McPhee Reservoir by the Great Cut Pumping Plant and conveyed 39.5 miles through the Dove Creek Canal and its 7.6-mile branch, the South Canal. Water for the Towaoc area is conveyed 48 miles from the reservoir by the Dolores Tunnel and the Dolores and Towaoc Canals. Both areas are served by sprinkler irrigation systems. The Montezuma Valley area is served by releases at Great Cut Dike and the Dolores Tunnel and Canal to an existing gravity distribution system.

Powerplants are located on McPhee Dam and the Towaoc Canal to generate an annual average of 36,578,000 kilowatt-hours, which enters the Colorado River Storage Project power transmission system. The McPhee Dam facility operates year-round on fishery releases from McPhee Reservoir, while the Towaoc Canal plant operates from April to October on the irrigation water supply conveyed through the canal.

McPhee Dam, located on the Dolores River, is a rolled earth, sand, gravel, and rockfill structure with a volume of approximately 6,230,000 cubic yards. The crest of the dam is 270 feet high above streambed, 1,300 feet in length, and 30 feet wide. A gated spillway located in the right abutment includes a concrete chute leading to a stilling basin. The outlet works, located in the left abutment of the dam, has two separate intake structures, and a total capacity of 5,000 cubic feet per second. Great Cut Dike is a rolled earthfill structure with a crest length of 1,900 feet, and crest width of 30 feet. It has a maximum height of 64 feet above original ground surface. The embankment has a volume of about 189,000 cubic yards.

McPhee Reservoir was created with the construction of McPhee Dam and the Great Cut Dike in a saddle on the Dolores-San Juan Divide. The reservoir has a total capacity of 381,195 acre-feet, including 229,200 acre-feet of active capacity, 151,900 acre-feet of inactive capacity, and 95 acre-feet of dead storage. The water surface area totals 4,470 acres at the top of the active capacity at an elevation of 6924.0 feet. The reservoir extends approximately 10 miles up the Dolores River, 4 miles up Beaver Creek, 1 mile up Dry Creek, 2 miles up House Creek, and 2 miles up the Great Cut saddle to the dike.

Great Cut Pumping Plant at Great Cut Dike consists of ten vertical, mixed-flow pumping units. Eight of the pumps are multi-stage and lift water from the reservoir through a discharge line into the Dove Creek Canal. The two remaining pumps lift water through a discharge line into the "U" lateral if the reservoir water surface is too low for gravity releases. Annual energy requirements for the eight pumps average about 5,800,000 kilowatt-hours. The additional two require an annual average of 99,000 kilowatt-hours.

Six pumping plants, including four along the Dove Creek Canal and two along the South Canal, provide water to pipe laterals for sprinkler irrigation. The average annual energy requirement for operating the plants is approximately 10,890,000 kilowatt-hours.

The Dove Creek Canal heads at the end of the pump discharge line at Great Cut Dike and extends northwest for 39.5 miles to Monument Creek Reservoir. It has an initial capacity of 380 cubic feet per second and a terminal capacity of 30 cubic feet per second. It includes a turnout to the South Canal and to the four sprinkler pumping plants.
The South Canal heads on the Dove Creek Canal near Pleasant View and extends 7.6 miles to the south and west. It has an initial capacity of 150 cubic feet per second and a terminal capacity of 35 cubic feet per second. It includes turnouts to three pressure pipeline sprinkler irrigation systems.

The Dolores Tunnel was drilled through the Dolores-San Juan divide about 2 miles west of the town of Dolores and 1 mile downstream from the existing tunnel of the Montezuma Valley Irrigation Company. Maximum capacity is 520 cubic feet per second.

The Dolores Canal heads at the outlet of the Dolores Tunnel and extend for 1.3 miles to the south and east. The canal replaced approximately 0.5 mile of the existing West Lateral and 0.8 mile of the existing East Lateral. Initial capacity is 520 cubic feet per second; the terminal capacity is 475 cubic feet per second.

The Towaoc Canal heads on the Dolores Canal 1.1 miles below the outlet of the Dolores Tunnel and extends southward for 45.4 miles to the full service lands in the Towaoc area. The canal is earth lined for 32.8 miles and concrete lined for 7.5 miles. It has an initial capacity of 135 cubic feet per second and a terminal capacity of 86 cubic feet per second.

The Cortez-Towaoc Pipeline heads just above the terminus of the Dolores Canal and extends southward 19.5 miles to near Towaoc. The initial section to Cortez carries 17.3 cubic feet per second and the remainder extending to Towaoc carries 2.9 cubic feet per second.

Twelve lateral systems with a total of 84.7 miles were constructed to deliver water to farms in the Dove Creek and Towaoc areas. Project drainage facilities were provided for both areas.

The McPhee Dam Powerplant consists of a penstock located within the outlet tunnel of the dam, a single turbine and generator at the base of the dam, and a 4.5 mile, 13.8-kilovolt transmission line to Great Cut Switchyard. Plant capacity is 990 kilowatt-hours, and produces an average of 6,260,000 kilowatt-hours annually.

Towaoc Canal Powerplant capacity is10.5 megawatts, and produces an average of 30,318,000 kilowatt-hours annually. A 78-inch-diameter, buried concrete pipe penstock heads at a project works on the Dolores Canal and extends southwest for about 11,700 feet into Hartman Draw to the powerhouse. The powerhouse consists of two turbines

connected to two 4.5-megawatt generators and one turbine connected to a 1.5-megawatt generator.

Operating agencies
The Dolores Water Conservancy District administers project and joint-use facilities within its boundaries, and the Ute Mountain Ute Indian Tribe and the Bureau of Indian Affairs administer facilities serving the reservation. The Forest Service, Bureau of Land Management, and Colorado Division of Wildlife participate in managing recreational and cultural facilities and wildlife lands.

Development History
In 1873, modern development began in southwest Colorado when the Federal Government opened the nearby San Juan Mountains to mining. In the early 1880's, settlers moved into the Montezuma Valley. These early settlers began farming the land but soon realized that to ensure good harvests they would need more water than was available from the small streams in the Montezuma Valley. To meet this need, they built irrigation canals that conveyed water from the Dolores river to the fertile but dry valleys in the San Juan river Basin. The canals did help, but they carried too little water and shortages continued to plague the farmers and residents. The Dolores Project ensures an adequate supply of water to meet existing and future agricultural and municipal needs.

Investigations
Definite plan studies were made and published in April 1977. The report updated the physical data and included revised financial and economic analysis of the project, based on the feasibility report transmitted to the Congress on March 17, 1966, which led to authorization.

Anticipated environmental impacts were detailed in the final environmental statement filed with the Council on Environmental Quality on May 9, 1977. Included in the studies were analyses of water resources, water quality, fisheries, wildlife, threatened or endangered species, scenery, economic and social conditions, historic and archeological sites, recreation, and a summary of unavoidable adverse impacts with short-term losses compared to long-term gains.

Archeological investigations disclosed that although the project would not affect any properties listed on the National Register of Historic Places, it could disturb about 487 known archeological sites, either within proposed rights-of-way or in other areas that would be altered by project construction. An excavation program preceded each stage of construction to remove and preserve all significant findings.

Authorization
The Dolores Project was authorized by the Colorado River Basin Act of September 30, 1968 (Public Law 90-537), as a participating project under the Colorado River Storage Project Act of April 11, 1956 (Public Law 84-485).

Construction
A ground breaking ceremony for the project was held September 24, 1977, at the site of the Great Cut Dike, northwest of Cortez.

Benefits

Irrigation
Project water is available for 61,660 acres and benefits the area's economy by increasing agricultural production, and strengthening service-related enterprises dependent on agriculture. Main crops are alfalfa, pasture, barley, oats, and corn silage for livestock feed.

Domestic, Municipal, and Industrial
The annual municipal and industrial water supply of 8,700 acre-feet will permit a moderate but healthy future growth in the area.

Recreation and Fish and Wildlife
Water releases from McPhee Reservoir created a downstream fishery. Releases from the reservoir in anticipation of snowmelt flows are managed to benefit white-water boaters. The project reservoirs and facilities provided new recreation opportunities for the public. Land acquired and managed for wildlife conservation created valuable and unthreatened habitat for a variety of wildlife species.

Hydroelectric Power
The average annual energy production of McPhee Dam and Towaoc Canal Powerplants is in excess of that needed by the project. Rather than draining the nation's energy resources, the Dolores Project generates environmentally clean power which helps alleviate the problems caused by dwindling fossil fuel supplies.

Flood Control
McPhee Reservoir provides flood protection for downstream landowners. The Dolores Project has provided accumulated actual benefits of $2,000 between 1950 and 1999.

Fruitgrowers Project

General Description
The Fruitgrowers Dam Project in southwestern Colorado furnishes irrigation water to nearly 2,700 acres of land immediately downstream from the dam. Structures built by the Bureau of Reclamation are Fruitgrowers Dam, Dry Creek Diversion Dam, and Dry Creek Diversion Ditch. Other diversion structures and the canal and lateral system were constructed by private interests.

Unit descriptions and facilities
Fruitgrowers Reservoir is filled from the natural flow of Alfalfa Run and by diversions from Surface and Dry Creeks. The flow of Dry Creek is diverted by the Dry Creek Diversion Dam, and conveyed through the Dry Creek Diversion Ditch. Surface Creek water is carried through the privately owned Alfalfa Ditch. Water stored in Fruitgrowers Reservoir is released and delivered to project lands through a privately owned system of canals and laterals.

The dam, located on Alfalfa Run, is 3 miles north of Austin, Colorado. It is an earthfill, rock-faced structure, 55 feet high and 1,520 feet long, containing 136,000 cubic yards of material. The reservoir stores a total of 4,540 acre-feet of water. The spillway, located on the left side of the dam, is an uncontrolled structure (meaning flows aren't regulated). A 76-foot-long concrete-lined channel discharges into a stilling basin which slows the velocity and reduces the energy of the water. The outlet works consists of one 3-foot diameter pipe controlled by two slide gates. This diversion dam is 13 feet high and 36 feet long. It contains 200 cubic yards of concrete. The Dry Creek Diversion Ditch is about 3 miles long and has a capacity of 100 cubic feet per second.

Operating agencies
The Orchard City Irrigation District assumed operation and maintenance of the project works in March 1940.

Development History
Irrigation of lands now encompassed by the Fruitgrowers Dam Project was initiated about 1890. In 1898, settlers built a small dam on Alfalfa Run to provide water storage for their irrigation system. This dam failed on June 13, 1937, resulting in extensive damage. Since the highly developed agricultural area could not be sustained without storage of the late summer water supply, the settlers requested that the Bureau of Reclamation investigate building a new dam.

Investigations
On the basis of their studies, Reclamation began work on the project in May 1938.

Authorization
Under section 4 of the act of June 25, 1910 (36 Stat. 835), the Secretary of the Interior recommended, and the President approved, construction of the project in January 1938. The primary purpose of the project is agriculture.

Construction
Reclamation completed construction of the new dam in time for stored water to be delivered to project lands for the 1939 irrigation season.

Benefits

Irrigation
The project provides supplemental irrigation for nearly 2,700 acres of land. Principal crops are fruit, small grains, corn, alfalfa, and pasture.

Recreation and Fish and Wildlife
When full, Fruitgrowers Reservoir has a surface area of 476 acres. It receives very little recreation use; however, bird watching is becoming increasingly popular. The reservoir is a major migration stop and nesting site for a variety of shorebirds and waterfowl.

Flood Control
Although there is no specific reservoir capacity assigned for flood control, the Fruitgrowers Project has provided an accumulated $4,000 in flood control benefits from 1950 to 1999.

Paonia Project

General Description
The Paonia Project, in west-central Colorado, provides full and supplemental irrigation water supplies for 15,300 acres of land in the vicinity of Paonia and Hotchkiss. Project construction includes Paonia Dam and Reservoir and enlargement and extension of Fire Mountain Canal. Paonia Dam controls and regulates the runoff of Muddy Creek, a tributary of the North Fork of the Gunnison River. No new irrigation laterals have been provided by the project.

Unit descriptions and facilities
Paonia Reservoir stores the flows of Muddy Creek upstream of its confluence with the North Fork of the Gunnison River. Downstream, the Fire Mountain Diversion Dam and Canal divert flows from the river for delivery to project lands in the Fire Mountain Division. Leroux Creek Division water, used downstream of the Fire Mountain Canal extension, is exchanged with the Fire Mountain Canal and Reservoir Company. These shares are used as project water by the Leroux Creek Water Users Association for irrigation of Leroux Division lands above the Fire Mountain Canal. Fire Mountain Division water is then used by the Leroux Division lands on Rogers Mesa downstream of the Fire Mountain Canal system. Improvement of existing small reservoirs in the Leroux Creek Division was accomplished independently by water users.

Paonia Dam is on Muddy Creek about 1 mile upstream of its junction with Anthracite Creek, which in turn forms the North Fork of the Gunnison River. The dam is an earthfill structure containing 1,302,000 cubic yards of embankment with an interior impervious zone, blanketed upstream and downstream by zones of sand, gravel, and cobbles. The upstream face is protected by a layer of riprap and the downstream face by a layer of rockfill. The crest of the dam is 35 feet wide and 770 feet long; the structure stands 199 feet above foundation.

The outlet works on the right abutment of the dam consists of a concrete intake tower, concrete-lined tunnel, gate chamber near the dam axis, and a combination stilling basin for both the outlet works and spillway. The outlet works also includes a concrete shaft house and concrete-lined shaft and add it between the gate chamber and access shaft. The capacity of the outlet works is 1,250 cubic feet per second at maximum water surface elevation.

The spillway, also on the right abutment, consists of an uncontrolled ogee crest and open chute having a design capacity of 12,500 cubic feet per second. The chute joins the combined outlet works-spillway stilling basin.

Paonia Reservoir has a surface area of 334 acres with a total capacity of 20,950 acre-feet and an active capacity of 18,150 acre-feet.

Fire Mountain Diversion Dam, located on the North Fork of the Gunnison River near Somerset, is a timber sheet-piling, rockfill structure. It has a height above streambed of 11 feet. Fire Mountain Canal extends 34.7 miles along the north side of the valley. It has an initial capacity of 200 cubic feet per second, reducing to 100 cubic feet per second at the Leroux Creek crossing.

Operating agencies
Operation and maintenance was assumed by the North Fork Water Conservancy District on June 1, 1962. By contract, the district transferred the physical operation and maintenance of the project to the Fire Mountain Canal and Reservoir Company.

Development History
Mining led to the early settlement of western Colorado and brought the area's first railroad service. The Ute Indians originally occupied west-central Colorado, including the valley of the North Fork of the Gunnison River. Early efforts to penetrate the area were resisted by the Utes until a compromise agreement with the Government was reached on September 4, 1881, and the Utes were moved to the Uintah Reservation in the Territory of Utah.

Water rights in the valley date from 1882. The development of irrigation facilities proceeded rapidly until, by the turn of the century, the late summer natural flow of the river had become heavily appropriated. Settlement and population growth were rapid in early years, but development of the area slowed by 1920. Agricultural settlement has remained more or less static since that time, although the population has increased.

Investigations
In 1934, the State of Colorado began investigating a number of reservoir sites, including five in the North Fork watershed. As a result of these investigations and activities of the local water users, the Bureau of Reclamation commenced investigation of storage possibilities in the North Fork Valley in 1936. A report issued by the Bureau of Reclamation in August 1938 suggested development of a reservoir at the Horse Ranch site on Anthracite Creek to serve lands of the Fire Mountain Canal and also of a reservoir

at the Beaver dam site on the East Fork of Minnesota Creek to supplement the water supply for ditches diverting from Minnesota Creek. Anthracite Creek and Minnesota Creek are tributaries of the North Fork of the Gunnison River. On the strength of this report, the Paonia Project was authorized on March 18, 1939, by Presidential approval of the findings of feasibility of the Secretary of the Interior, dated March 16, 1939. Subsequent findings prompted issuance of a revised report in 1940 dealing only with the Fire Mountain Division. This report proposed that the Spring Creek Reservoir site on East Muddy Creek, another tributary of the North Fork, be developed by the Bureau of Reclamation and that the Fire Mountain Canal be enlarged by the water users in a 10-year development period during which no payments would be required for the storage dam. Funds for the canal enlargement were to be derived from charges made for the use of Spring Creek Reservoir water and from revenues from the sale of Leroux Creek water rights in the area to be served by an extension of the Fire Mountain Canal. This plan, however, was not favored by water users and authorization was not requested.

In 1946, the project plan was further revised to include a total of 14,750 acres of land to be benefited, to provide 4,000 acre-feet of surplus reservoir capacity, to provide for enlargement and improvement of the Overland and Fire Mountain Canals, and to provide for transfer of the use of water to upstream lands on Leroux Creek under two alternative plans. The project was authorized on June 25, 1947, by the 80th Congress. When bids for construction of Spring Creek Dam were opened on August 3, 1948, the low bid was 54 percent above the engineer's estimate and exceeded the total expenditure authorized for all features. No justification could be found for such high bids, and all bids were rejected. It was determined, however, that enlargement and extension of the Fire Mountain and Overland Canals were feasible undertakings independent of the storage feature. Because repayment contracts had been executed between the Government and the water users, construction of the Fire Mountain Canal was commenced.

In a February 1951 report, the project plan was revised to include an 18,000 acre-foot reservoir at the Paonia site, additional extension of the Fire Mountain Canal, enlargement of Overland Ditch, and construction of a siphon and pumping plant to convey irrigation water from the Fire Mountain Canal to 2,010 acres of land along Minnesota Creek. This plan would have provided irrigation service for 14,830 acres of irrigated land and 2,210 acres of unirrigated land. Development was authorized in 1956 as a participating project with the Colorado River Storage Project.

Since the 1956 authorization, water users in the Minnesota Creek area have withdrawn from the project in favor of private development of a reservoir on that stream. Therefore, the Minnesota Siphon and Pumping Plant and service to the Minnesota Creek lands were eliminated from the plan. It also was determined that existing ditches from Leroux Creek were adequate to convey usable flows of that stream, and enlargement of Overland Ditch was deleted from the plan. In the definite plan studies, it was determined that the total reservoir capacity should be increased to 21,000 acre-feet to provide more space for sediment retention. Irrigable acreages were reduced to 15,300.

Authorization
Construction under the 1938 plan was authorized by the President under Reclamation law on March 18, 1939.

The revised plan was authorized by the Congress on June 25, 1947. The project was reauthorized as a participating project under the Colorado River Storage Project by the act of April 11, 1956 (70 Stat. 105). The primary purpose of the project was for agriculture.

Construction
The contract for the construction of Paonia Dam was awarded January 7, 1959, and work was completed in January 1962. Contracts for extension and lining of Fire Mountain Canal were awarded in 1959 and 1960, and work was completed in 1962.

Benefits

Irrigation
The project assures a full supply of water for irrigated lands. The general type of farming formerly practiced in the area has been continued with project development, but the additional irrigation supplies make possible more intensive crop production. Livestock feed and apples, peaches, and cherries are the major crops grown. Dairy and beef cattle are the principal livestock of the area.

Recreation and Fish and Wildlife
Fishing, hunting, picnicking, and water sports are available at Paonia Reservoir. Recreation facilities are administered by Colorado State Parks. Visitor days totaled 8,345 in 1996.

Flood Control
Flood dangers on North Fork River are reduced by emptying the reservoir each year and by reserving storage space through forecasts of snowmelt runoff, and regulation of flood flows. The Paonia Reservoir has 2,280 acre feet of capacity assigned to flood control. The Paonia Project has provided an accumulated $253,000 in flood control benefits from 1950 to 1999.

Smith Fork Project

General Description
Flows of Smith Fork, Iron, Mud, and Alkali Creeks are regulated and utilized by the Smith Fork Project in west-central Colorado. The project, about 30 miles southeast of Delta, Colorado, supplements the irrigation water supply for approximately 8,200 acres in Delta and Montrose counties and provides a full water supply for 1,423 acres of land previously not irrigated. Construction features of the project include Crawford Dam and Reservoir, Smith Fork

Diversion Dam, Smith Fork Feeder Canal, Aspen Canal, Clipper Canal, and recreation facilities.

Unit descriptions and facilities

Crawford Dam is on Iron Creek, a tributary of the Smith Fork about 1 mile south of Crawford, Colorado. The Crawford Reservoir regulates flows of Iron Creek and its tributaries as well as the surplus flows of the Smith Fork of the Gunnison River, diverted to the reservoir by the feeder canal. Small quantities of reservoir storage water are released to Iron Creek and diverted by several small private ditches. The remainder is released to Aspen Canal for conveyance to private ditches for distribution. Some of the storage releases through Aspen Canal replace former direct flow diversions from Smith Fork, permitting additional direct flow diversions for project land higher on the stream.

Crawford Dam is an earthfill structure 162 feet high and 580 feet long, with a volume of 1,006,000 cubic yards. The uncontrolled overflow spillway is in the left abutment of the dam and has a capacity of 1,400 cubic feet per second. The outlet works in the right abutment of the dam carries water through a 34-inch-diameter steel pipe controlled by four 2.25-foot-square high-pressure gates. Maximum discharge capacity to Aspen Canal is 125 cubic feet per second. Crawford Reservoir has a total capacity of 14,395 acre-feet and an active capacity of 14,064 acre-feet. The reservoir has a surface area of 406.2 acres.

Smith Fork Diversion Dam, at the head of Smith Fork Feeder Canal, consists of a concrete ogee weir and embankment wings. The dam is about 3 miles northeast of Crawford, stands 10 feet above streambed, has a total crest length of 790 feet, and a weir crest length of 34.6 feet. Diversion capacity of the structure is 80 cubic feet per second.

In the vicinity of Crawford, the earth-lined Smith Fork Feeder Canal originates at Smith Fork Diversion Dam and runs southwesterly to Crawford Reservoir. The 2.4-mile-long canal has an initial capacity of 80 cubic feet per second.

Aspen Canal heads at Crawford Dam and runs 5.8 miles in a northerly direction. The canal has an initial capacity of 125 cubic feet per second.

Clipper Canal feeds from Aspen Canal and runs to the west a distance of about 0.5 mile. The initial capacity of the canal is 60 cubic feet per second.

Operating agencies

Operation and maintenance of the project was turned over to the Crawford Water Conservancy District on January 1, 1964.

Development History

Delta County, along with most of western Colorado, was originally inhabited by the Ute Indians. Early settlement of the area was retarded by hostility between the Utes and the immigrants. In 1881, a compromise agreement was reached between the Federal Government and the Utes which required the Indians to locate in the Uintah Reservation

in the Territory of Utah. After this agreement, settlement of the area progressed rapidly. Most of the impetus of the initial settlement period was provided by discoveries of rich deposits of gold, silver, and other minerals in the mountainous areas near the Continental Divide. Agricultural development proceeded at a slower rate but was much more uniform and stable. Farms were developed along the valleys, towns were established near the mines and the agricultural communities, and construction of railroads to the trade and mining centers was begun.

Investigations
The Smith Fork Project was mentioned briefly in Reclamation's basin-type report of March 1946 on the Colorado River. In 1951, Reclamation issued a detailed report on the Smith Fork Project as a supplement to the 1951 report on the Colorado River Storage Project and participating projects. This second report, amended in October 1953, was the basis on which the project was authorized.

Authorization
The project is one of the initial participating projects authorized with the Colorado River Storage Project by the act of April 11, 1956 (70 Stat. 105). The primary purpose of the project is agriculture.

Construction
Construction was begun on Crawford Dam in 1960 and on all other major features in 1961. All construction was completed in 1962.

Benefits

Irrigation
An improved irrigation supply permits new lands to be irrigated and permits better crop yields on lands previously inadequately watered. Predominant crops include alfalfa, grass hay, pasture, barley, oats, wheat, and corn. Feed production is used for livestock, primarily cattle and sheep.

Recreation and Fish and Wildlife
Recreation at Crawford Reservoir is administered by the Colorado State Parks and consists of fishing, boating, and camping. Visitor days in 1996 totaled 109,704. In 1997, the State of Colorado and Bureau of Reclamation upgraded facilities at Crawford State Park to include accessible features for people with disabilities. There are 45 campsites with hookups and 21 without. Showers and flush toilets are available. A fishing trail with platforms and an accessible dock are also available.

Flood Control
Although there is no specific reservoir capacity assigned for flood control, the Smith Fork Project has provided an accumulated $14,000 in flood control benefits from 1950 to 1999.

Uncompahgre Project

General Description
The Uncompahgre Project is on the western slope of the Rocky Mountains in west-central Colorado. Project lands surround the town of Montrose and extend 34 miles along both sides of the Uncompahgre River to Delta, Colorado. Project features include Taylor Park Dam and Reservoir, Gunnison Tunnel, 7 diversion dams, 128 miles of main canals, 438 miles of laterals, and 216 miles of drains. The systems divert water from the Uncompahgre and Gunnison Rivers to serve over 76,000 acres of project land.

Unit descriptions and facilities
The project plan provides for storage in Taylor Park Reservoir on the Taylor River, which is a part of the Gunnison River Basin, and diversion of water from the Gunnison River by the Gunnison Diversion Dam through the Gunnison Tunnel and the South Canal to the Uncompahgre River. To distribute the waters of the Gunnison and Uncompahgre Rivers, the South and West Canals were constructed and the larger existing private canals, that take water directly from the Uncompahgre River, were purchased, then enlarged and extended. Laterals were constructed to deliver water from the South Canal to project lands.

Taylor Park Dam is on the Taylor River, a tributary of the Gunnison River. The dam is a zoned earthfill structure 206 feet high, with a crest length of 675 feet and a volume of 1,115,000 cubic yards. It creates a reservoir with a storage capacity of 106,200 acre-feet. The spillway is an overflow-type weir crest 180 feet long with a capacity of 10,000 cubic feet per second. The outlet works is a horseshoe tunnel with a diameter of 10 feet, and a capacity of 1,500 cubic feet per second.

The Gunnison Diversion Dam on the Gunnison River, about 12 miles east of Montrose, is a timber-crib weir with concrete wings and a removable crest. The dam has a structural height of 16 feet. It diverts Gunnison River direct flows, as well as releases from the Taylor Park Dam into the Gunnison Tunnel. The Gunnison Tunnel was designed as a rectangular section 11 feet wide and 12 feet high, with an arch roof. A number of modifications have been made since the original construction. It is 5.8 miles long and has a capacity of 1,300 cubic feet per second.

The South Canal extends from the end of the Gunnison Tunnel generally southwest 11.4 miles to the Uncompahgre River. Part of the canal is concrete lined; the remainder is unlined. The canal has an initial capacity of 1,010 cubic feet per second.

West Canal extends generally northwest about 21 miles from the Uncompahgre River beginning at the terminal structure of the South Canal with the river. This unlined canal as an initial capacity of 172 cubic feet per second. The West Canal is diverted directly from the South Canal and a timber and metal flume carries the canal across the Uncompahgre River. There is a small diversion for winter flows directly from the Uncompahgre River.

Montrose and Delta Diversion Dam is on the Uncompahgre River about 8 miles south of Montrose. The dam is a concrete gate structure with radial control and sluiceway gates. The unlined canal extends generally northwest about 40 miles from the diversion point and has a diversion capacity of 563 cubic feet per second. The original dam and canal were privately constructed and later purchased and rehabilitated by Reclamation as part of the Uncompahgre Project. A new structure was built in 1963 with a diversion capacity of 550 cubic feet per second.

Loutzenhizer Diversion Dam is on the Uncompahgre River about 2 miles south of Montrose. It was a pile-and-timber weir with a concrete apron but was rebuilt by the water users into a concrete weir and apron with radial gates. The dam has a structural height of 24 feet. The canal extends generally northwest 14.5 miles from the diversion dam and has a diversion capacity of 120 feet per second. The original dam and canal were privately constructed and purchased by Reclamation in 1908.

Selig Diversion Dam is on the Uncompahgre River about 5 miles northwest of Montrose. It has a timber-gated sluiceway with uncontrolled concrete overflow weir and concrete stilling basin. Its structural height is 25 feet. The canal extends generally north about 20 miles from the diversion dam. This unlined canal has a diversion capacity of 320 cubic feet per second. The original dam and canal were privately constructed and purchased by Reclamation in 1914.

Located on the Uncompahgre river about 8 miles northwest of Montrose, the Ironstone Diversion Dam is a concrete structure with radial control and sluiceway gates with a concrete wing. The structural height is 17 feet. The unlined canal runs 14 miles northwest from the diversion dam. The diversion capacity of the canal is 400 cubic feet per second. The original dam and canal were privately constructed and were acquired by Reclamation in 1915.

Located on the Uncompahgre river about 10 miles northwest of Montrose, the East Canal Diversion Dam is a concrete and timber weir with an earth embankment wing. The structural height is 16 feet. The unlined canal extends 10.6 miles north from the diversion dam. Its diversion capacity is 165 cubic feet per second. The original dam and canal were privately constructed and were acquired by Reclamation in 1911.

The Garnet Diversion Dam is on the Uncompahgre River about 15 miles northwest of Montrose. The dam is a concrete-surfaced rockfill weir, and has a structural height of 8 feet. Garnet Canal is unlined and extends 10.7 miles northwest from the diversion dam. Its diversion capacity is 75 cubic feet per second. The original dam and canal were constructed by private interests and purchased by the Bureau of Reclamation in 1914.

There are 438 miles of laterals which distribute water to project lands. A system of subsurface drains totaling 216 miles has been constructed.

Operating agencies
The project is operated and maintained by the Uncompahgre Valley Water Users Association.

Development History
The lands comprising the project area were formerly part of the Ute Indian reservation. Settlement rapidly followed cession of the land by the Indians to the United states. By 1903, about 30,000 acres in the Uncompahgre Valley were irrigated by private systems which included five diversion dams on the Uncompahgre River. As the possibilities for greater use of irrigation water were evident, a larger development by the State of Colorado was started in 1901 but was abandoned. Work by the Reclamation Service began in 1903.

Active support for driving a tunnel from Gunnison River to the Uncompahgre Valley to obtain additional water was solicited as early as 1890. In 1894, the Geological Survey completed a reconnaissance survey and found it was too expensive an undertaking for local interests, but in 1901 the state of Colorado appropriated $25,000 to start the tunnel. Only 900 feet were driven before the funds were exhausted. In 1901, construction surveys of the project were begun by the Geological Survey, and the general scheme of the project was outlined in its first report. After the passage of the Reclamation Act in 1902, the Uncompahgre Valley was selected for immediate development. The original surveys by the Geological survey, plus the investigational work carried out by the Reclamation Service, served as a basis for authorization of the project in 1903.

Authorization
The Uncompahgre Project (originally called the Gunnison Project) was authorized by the Secretary of the Interior on March 14, 1903, under the provisions of the Reclamation Act. Rehabilitation of the project and construction of Taylor Park Dam was approved by the President on November 6, 1935.

Construction
Construction began in July 1904, and the first water for irrigation was available during the season of 1908 from the Uncompahgre River. The Gunnison Tunnel was completed in 1909, and the Gunnison Diversion Dam was completed in January 1912. The project was transferred to the Uncompahgre Valley Waters Users Association for operation and maintenance in 1932. Taylor Park Dam, built from funds allotted under the National Industrial Recovery Act, was completed in 1937. Other improvements made during the same period included enlargement, lining, and smoothing portions of the Gunnison Tunnel, constructing concrete and steel structures to replace some of the worn out wooden structures in the privately constructed irrigation systems, relining portions of the canals, and constructing a drainage system to relieve and prevent water logging of land.

Recent Developments
This project is within the Colorado River basin and is part of the Colorado River Basin Salinity Control Program., specifically The Lower Gunnison Basin Salinity Control Unit

Benefits

Irrigation
Almost 76,300 acres of land receive a full irrigation water supply from the facilities of the project. Principal crops are alfalfa, wheat, corn, oats, potatoes, beans, barley, onions, and fruit.

Recreation and Fish and Wildlife
Free camp and picnic grounds have been provided by the Forest Service at Taylor Park Reservoir. Cabins are available at privately owned resort developments in the area. Camping, picnicking, swimming, and boating are popular activities, and fishing is good for rainbow, and brown trout. Some brook and native trout also are caught.
Flood Control
Although there is no specific reservoir capacity assigned for flood control, the Uncompahgre Project has provided an accumulated $639,000 in flood control benefits from 1950 to 1999.

Table 1-Average Annual Project Depletions

Project	Average Annual Depletion (Acre-feet)	Existing Section 7 Coverage
Wayne Aspinall Unit (Evaporation)	7,000-9,000	No
Wayne Aspinall Unit (Water Service Contracts)	<1,000	Yes
Bostwick Park Project	4,000	No
Dallas Creek Project	17,200	Yes
Dolores Project*	99,200	Yes
Fruitgrowers Project	4,100	No
Smith Fork Project	6,000	No
Paonia Project	10,000	No
Uncompahgre Project	155,000	No
Total	**335,300-337,300**	

*Existing Biological Opinion for the Dolores Project references release from upstream projects.

Attachment 2—Summary of Flow Recommendations to benefit endangered fishes in the Colorado and Gunnison rivers.

The Flow Recommendations generally call for higher spring peak flows and lower base flows to produce a more natural river hydrograph. Flow Recommendations are designed to meet the physical and biological needs of the endangered fishes. A summary of the Flow Recommendations is provided below. To review the entire report, go to Http://www.usbr.gov/uc/wcao/rm/aspeis/pdfs/GunnCoFlowRec.pdf.

RECOMMENDATION GOALS

→ Provide habitats and conditions that provide for spawning and reproduction;

→ Provide in-channel habitat for all life stages for endangered fish;

→ Provide backwater habitat and conditions necessary for overall fish health; and

→ Provide base flows that promote growth and survival of young fish during summer, autumn, and winter.

HYDROLOGIC CATEGORIES (Runoff varies year to year, dependent on snowpack)

→ **Wet (0--10% exceedance).—**A year during which the forecasted April—June runoff volume has been equal or exceeded in 10% or less of the years since 1937. This hydrologic condition has a 10% probability of occurrence.

→ **Moderate Wet (10--30% exceedance).**—A year during which the forecasted April—July runoff volume has been equaled or exceeded in 10-30% of the years since 1937. This hydrologic condition has a 20% probability of occurrence.

→ **Average Wet (30—50% exceedance).**—A year during which the forecasted April—July runoff volume has been equaled or exceeded in 30—50% of the years since 1937. This hydrologic condition has a 20% probability of occurrence.

→ **Average Dry (50—70% exceedance).**—A year during which the forecasted April—July runoff volume has been equaled or exceeded in 50—70% of the years since 1937. This hydrologic category has a 20% probability of occurrence.

→ **Moderate Dry (70—90% exceedance).**—A year during which the forecasted April—July runoff volume has been equaled or exceeded in 70—90% of the years since 1937. This hydrologic condition has a 20% probability of occurrence.

→ **Dry (90—100% exceedance).**—A year during which the forecasted April—July runoff volume has been equaled or exceeded in 90% or more of the years since 1937. This hydrologic condition has a 10% probability of occurrence.

INFLOWS TO BLUE MESA UNDER HYDROLOGIC CATEGORIES

→ **Wet**— Over 1,123,000 af (≥ 161% of average).

→ **Moderately Wet**— Between 871,000 af and 1,123,000 af (125—161% of average).

→ **Average Wet**— Between 709,000 and 871,000 af (102—125% of average).

→ **Average Dry.**— Between 561,000 and 709,000 af (80—102% of average).

→ **Moderately Dry.**— Between 381,000 and 561,000 (55—80% of average).

→ **Dry.**— Less than 381,000 af (< 55% of average).

SUMMER THROUGH WINTER BASE FLOW RECOMMENDATION FOR THE GUNNISON AND COLORADO RIVERS

Hydrologic Category	Gunnison River at Whitewater	Colorado River at Stateline
Wet; 0—10% Exceedance	1,500—2,500 cfs[2]	3,000—6,000 cfs
Moderately Wet; 10—30% Exceedance	1,050—2,500 cfs	3,000—4,800 cfs
Average Wet; 50—70% Exceedance	≥1,050—2,000 cfs	3,000—4,800 cfs
Average Dry; 50—70% Exceedance	≥1,050— ≥2,000 cfs	2,500—4,000 cfs
Moderately Dry; 70—90% Exceedance	≥750— ≥1,050 cfs	2,500—4,000 cfs
Dry; 90—100% Exceedance	≥750— ≥1,050 cfs	≥1,800 cfs

[2] cfs = cubic feet per second

SPRING PEAK-FLOW RECOMMENDATIONS FOR THE GUNNISON RIVER NEAR GRAND JUNCTION[3]

Hydrologic Category	Expected Occurrence	Flow Target and Duration[4]		Instantaneous Peak Flow (cfs)
		½ Fullbank Discharge Days/Year ≥ 8,070 cfs	Fullbank Discharge Days/Year ≥ 14,350 cfs	
Wet	10%	60—**100**	15—**25**	15,000—23,000[5]
Moderately Wet	20%	40—**60**	10—**20**	14,350-16,000[C]
Average Wet	20%	20—**25**	2—**3**	≥ 14,350[6]
Average Dry	20%	10—**15**	0—**0**	≥ 8,070[d]
Moderately Dry	20%	0—**10**	0—**0**	≥ 2,600[7]
Dry	10%	0—**0**	0—**0**	~ 900—4,000[8]
Long-term Weighted Average[9]		20—**32**	4—**7**	

For example, in a moderately wet year, flows of 14,350 cfs are recommended for 10-20 days.

[3] This table represents one possible way of achieving the long-term weighted average for sediment transport.
[4] Lower value in each range is for maintenance, higher (bold) value in each range is for improvement.
[5] Instantaneous peak flows within this range have occurred in these hydrologic categories since Blue Mesa Reservoir was closed. The observed instantaneous peaks are desired in the future in conjunction with meeting the flow targets. No specific peak flow with this range is recommended to ensure continued variability among years.
[6] Expected minimum peak flow when recommendations are met; actual peak may exceed the value, ensuring continued variability among years.
[7] Instantaneous peak flow that has occurred since Blue Mesa was closed. Peak flows are expected to equal or exceed this level in years when 8,070 cfs is not reached.
[8] Range of peak flows within this category that have occurred since Blue Mesa Reservoir was closed. Lowest number reflects base flow. Peak flows are expected to continue to occur within this range; no specific flow within this range is recommended, ensuring variability among years.
[9] Weighted values equals days/year x expected occurrence (the sum of all weighted average values equals the long-term weighted average in days/year.

SPRING PEAK-FLOW RECOMMENDATIONS FOR THE COLORADO RIVER NEAR THE COLORADO—UTAH STATE LINE[10]

Hydrologic Category	Expected Occurrence	Flow Target and Duration[11]		Instantaneous Peak Flow (cfs)
		½ Fullbank Discharge Days/Year ≥ 18,500 cfs	Fullbank Discharge Days/Year ≥ 35,000 cfs	
Wet	10%	80—**100**	30—**35**	39,300—69,800[12]
Moderately Wet	20%	50—**65**	15—**18**	35,000—37,500[13]
Average Wet	20%	30—**40**	6—**10**	≥ 35,000[14]
Average Dry	20%	20—**30**	**0**	18,500—26,600[d]
Moderately Dry	20%	0—**10**	**0**	9,970—27,300[15]
Dry	10%	**0**	**0**	5,000—12,100[f]
Long-term Weighted Average[16]		28—**39**	7.2—**9.1**	

[10] This table represents one possible way of achieving the long-term weighted average for sediment transport.
[11] Lower value in each range is for maintenance, higher (bold) value in each range is for improvement.
[12] Instantaneous peak flows within this range have occurred in these hydrologic categories since Blue Mesa Reservoir was closed. These observed instantaneous peaks are desired in the future in conjunction with meeting the flow targets. No specific peak flow is recommended to ensure continued variability among years.
[13] Lower number reflects the expected minimum peak flow when recommendations are met and the upper number reflects peak flows that have occurred since Blue Mesa Reservoir was closed. Peak flow is expected to occur within this range, but no specific value is provided to ensure variability among years.
[14] Expected peak flow when flow recommendations are met. Actual peak may exceed this level ensuring variability among years.
[15] Range of peak flows that have occurred since Blue Mesa Reservoir was closed. Peak flows are expected to continue to fall within this range when 18,500 cfs is not reached. No specific recommendation within this range is made to ensure variability among years.
[16] Weighted values equals days/year x expected occurrence (the sum of all weighted averages equals the long-term weighted average in days/year).

Attachment 3 Aspinall Unit Operations, Consideration of Discretionary vs. Non-Discretionary Actions

LOCATION	OPERATION	BACKGROUND	DISCRETION
A. Blue Mesa Dam	1. End of December target: 7490.0 feet or lower	Based on studies and experience to minimize flooding due to icing upstream near the town of Gunnison. By verbal agreement, Reclamation has usually operated for an end of December icing target of 7490.00 feet elevation since 1980.	Yes
	2. Reservoir target fill: 7517.4 feet by end of runoff season (June-July) and a March 31 target related to flood control.	7517.4 feet is 2 feet from top of spillway gate elevation 7519.4 feet (official full pool). The 2 feet of elevation is a safety factor for controlling the reservoir in case of sudden flood events such as thunderstorms or very high snowmelt inflow.	Yes
	3. Peaking operations: Releases fluctuate between 0 and full powerplant capacity to meet variations in load requirements.	Curecanti Unit, Economic Justification Report, April 1962	Yes
	4. Maintain reservoir elevation to allow hydropower operations	Maintain reservoir above 7393 feet (top of inactive storage)	Yes
	5. Option to draw reservoir down to dead pool if needed.	While unlikely, situations may develop requiring full use of reservoir in a particular year.	Yes

B. Morrow Point Dam	1. Tour boat operations: Attempt to hold reservoir between 7151.0 and 7158.5 feet during the recreation season (May 1-September15) when the tour boat is in operation. When the tour boat is not in operation (September 15-April), the minimum reservoir elevation is 7144.0	Morrow Point Standing Operating Procedure. These elevations are not a strict rule and may be periodically modified to address other needs.	Yes
	2. Drawdown restrictions: To minimize the risk of movement of landslides within the reservoir, the reservoir drawdown rate is limited to a maximum of 3 feet per day at reservoir elevations below 7144 feet For reservoir elevations above 7144, if the reservoir drawdown rate is expected to be greater than 3 feet per day, then visual observations should be made of landslide A.	Morrow Point Standing Operating Procedure	No-However, restrictions include geological observations that may allow modifications in any particular year.
	3. Peaking operations: Flows fluctuate between 0 cfs and full powerplant capacity to meet variations in load requirements	Curecanti Unit, Economic Justification Report, April 1962	Yes
C. Crystal Dam	1. River regulation: Flows relatively uniform. When the powerplant is operating at full capacity, fluctuations could be in the 200 cfs range because the programmable logic control cannot be used at full powerplant capacity.	Curecanti Unit, Economic Justification Report, April 1962 and 1971 Crystal Dam final environmental impact statement**.**	No River regulation is non-discretionary but some minor fluctuation due to reservoir elevations.
	2. Ramping rates: 500 cfs per day (15%) change for ramping up, and 400 cfs per day (15%) for ramping down.	Ramp rates set for safety of people recreating in the canyon; for fishery considerations; for downstream water users.	Yes
	3. Drawdown restrictions	Dry season drawdown limited to 10 feet in 24 hours and 15 feet in 72 hours. Wet season drawdown limited to 5 feet in 24 hours and 20 feet per week.	No
D. Spring Peak	1. Determined annually by Reclamation with input from the Aspinall	Historic practice to benefit fish and recreation, channel maintenance, and general	Yes

	operations meeting. ▪ Total volume determined from amount of bypass hydrologically necessary. ▪ Normally scheduled in May/June timeframe based on the May 1 forecasts. ▪ Bypass flows consolidated over a shorter timeframe than average.	health of the river. During the January through April period, operations will attempt to reduce the amount of spring bypasses; however, it is recognized that there would be discretion in action alternatives to bypass Aspinall Unit powerplants while providing endangered fish flows.	
E. Black Canyon of the Gunnison and Gunnison Gorge	1. Minimum flow of 300 cfs at the "Below Tunnel" gage under normal conditions; 200 cfs under drought and emergency conditions	State of Colorado 300 cfs junior Gunnison right except in cases of significant drought (as determined by reservoir elevation projections) and Aspinall Unit emergencies.	No
	2. Use of excess water to provide spring peak	For general environmental purposes.	Yes
	3. Avoidance of flow decreases after October 15 when practical; avoidance of flow decreases after April 1 when practical.	Brown trout and rainbow spawn; based on experience and CDOW input	Yes
F. Gunnison River at Delta, Colorado	1. Operate to attempt to prevent flows form exceeding 15,000 cfs at Delta, Colorado	As described in Water Control Manual US Army Corps of Engineers, February 1988	No
	2. Monitor flood conditions at Delta and attempt to reduce damage that can occur below 15,000 cfs	Delta reports that flood damage can begin to occur in the 10,000 to 12,000 cfs range	Yes
G. Redlands Fish ladder	1. Deliver 100 cfs to Redlands fish ladder (June-September)		Yes
	2. Deliver up to 40 cfs to Redlands fish screen (ice-free period)	Diversion canal reduction due to fish screen.	Yes
	3. Provide migration flows of 300 cfs downstream from Redlands fish ladder	Most important during period that fish ladder is operating	Yes
H. Existing Commitments	1. Water sales contracts	Existing water contracts for use of Blue Mesa water	No
	2. Upper Gunnison Subordination Agreement-Allows junior water users within the natural basin of the Gunnison River to	In long-term, could mean up to 60,000 af additional depletions in Upper Gunnison Basin in the future	No

	develop up to a total of 60,000 acre-feet of depletions without interference from the Aspinall Unit.		
	3. Colorado water law and the Law of the River		No
	4. 1975 Taylor Park-Aspinall Unit exchange agreement		No.
	5. Power Contracts	CRSP power contracts are not "unit specific" but apply to integrated power facilities.	No discretion on following contracts; however, flexibility within contracts to address changing hydrologic conditions and compliance with other laws.
	6. Meet power system requirements	NERC and WECC reliability requirements (i.e. reserve voltage control, etc.)	No
I. Dallas Creek and Dolores Project Biological Opinions	1. Offset impacts of the depletions from the Dallas Creek and Dolores Projects on endangered fish	Opinions call for upstream Reclamation reservoir to offset the impacts	No

ASPINALL UNIT HYDRAULIC CAPACITIES-no discretion

Capacities (acre-feet)	Blue Mesa	Morrow Point	Crystal
Dead storage	111,200	165	7,700
Inactive storage	81,070	74,905	4,650
Active storage	748,430	42,120	12,890
Live storage*	829,500	117,025	17,540
Total storage	940,700	117,190	25,240
Outlet capacities (cfs)			
Powerplants (max)	2,600-3,400	5,000	2,150
Powerplant bypass	4,000-5,100	1,500	1,900-2,200
Combined powerplant and bypass(max)	6,100	6,500	4,350
Spillway	34,000	41,000	41,350

*-Live storage is the combination of the active and inactive storage. It represents storage that physically can be released from the reservoir.

-Crystal powerplant capacity may be adjusted following testing-the new capacity may affect reservoir targets.

-Blue Mesa Reservoir shares one penstock for both river outlet and powerplant releases; the combined releases of these two are constrained to about 6,100 cfs.

-The hydraulic capacities shown in the table assume full reservoir conditions. At lower elevations, the hydraulic capacity would be less. Also system efficiencies may affect the hydraulic capacity.

-Full capacity may not always be available due to scheduled maintenance, equipment malfunction, or power system reserve requirements.

-There are no specific recreation or fishery pools in the reservoirs.

Attachment 4--Number of Cross Sections reaching ½ bankfull or bankfull levels at various Gunnison River flow levels; from Pitlick et al. data (1999)

Flow	No. X-sections ½ bankfull	Flow	No. X-sections bankfull
4660	1	7352	1
4728	2	8838	2
4895	3	9315	3
4951	4	10260	4
5117	5	10719	5
5144	6	10738	6
5316	7	10952	7
5359	8	11391	8
5576	9	11485	9
5988	10	11741	10
6025	11	11834	11
6031	12	11933	12
6186	13	11944	13
6668	14	11987	14
6836	15	12419	15
6893	16	13039	16
6900	17	13069	17
6930	18	13101	18
7017	19	13202	19
7037	20	13250	20
7200	21	13310	21
7285	22	13324	22
7404	23	13387	23
7711	24	13629	24
7906	25	13832	25
8044	26	14283	26
8047	27	14311	27
8098	28	14338	28
8107	29	14347	29
8303	30	14366	30
8393	31	14495	31
8440	32	14573	32
8571	33	14901	33
8719	34	15582	34
8787	35	15948	35
8847	36	15984	36
8997	37	16041	37
9157	38	16110	38
9285	39	16940	39
9345	40	17162	40
9474	41	17806	41
9492	42	18132	42
9580	43	18534	43
9823	44	19282	44
10229	45	21976	45
11081	46	22140	46
11236	47	22959	47
11532	48	23179	48
11674	49	23297	49
11717	50	23418	50
11860	51	24846	51
12033	52	24699	52
12658	53	25565	53
12695	54	28719	54

Attachment 5. Summary of water quality data

5.1 Data collected by the USGS from 1968-1998 for the Gunnison River at the Whitewater gage (from Butler 2000)

Parameter	Number of samples	Period collected	Median	Maximum	Minimum	90th percentile concentration
Oxygen, mg/L	244	70-98	9.2	13.7	6.4	11.6
pH	335	68-98	8.1	8.9	6.7	8.4
Fecal coli-form, counts/100 ml	108	76-95	58	1,100	1	360
Unionized ammonia, mg/L	142	80-98	.001	.022	0	.004
Unionized ammonia, total mg/L	83	78-92	.001	.011	0	.005
Nitrite mg/L	100	81-98	.01	.06	<.01	.02
Nitrite + nitrate, mg/L	200	70-98	.78	2.9	.1	1.6
Chloride, mg/L	337	68-98	8.2	58	1.9	16
Sulfate, mg/L	337	68-98	310	950	60	670
Boron microgram/L	33	68-71 91-92	50	300	0	140
Hardness, mg/L	337	68-98	360	875	107	608
Arsenic, total Microgram/L	66	75-91	1	7	<1	3
Arsenic Microgram/L	66	75-91	1	7	<1	3
Cadmium Microgram/L	65	75-91	<1	10	<1	2
Chromium Microgram/L	65	75-91	<1	10	<1	2
Copper Microgram/L	65	75-91	2	23	<2	7

Iron, total Microgram/L	28	75-82	955	8,800	190	3,100
Iron, Microgram/L	170	71-98	13	1,500	<3	60
Lead Microgram/L	66	75-91	1	71	<1	9
Manganese total, Microgram/L	28	75-82	60	260	30	190
Manganese Microgram/L	170	71-98	14	140	<10	40
Mercury, dissolved Microgram/L	64	75-91	<.1	.3	<.1	.1
Nickel, Microgram/L	62	75-91	1	28	<1	4
Selenium, Microgram/L	132	75-98	5	25	<1	10
Selenium, total Microgram/L	28	75-82	10	21	4	19
Silver, Microgram/L	70	75-91	<1	1	<1	<1
Zinc, Microgram/L	66	75-91	7	82	<3	21

Table 5.2. Parameters exceeding the 85th percentile or had occasional exceedances of State Standards.

[Chemical constituents are dissolved unless otherwise noted; ammonia for USGS data at station 09144250 is combined dissolved and total data; *, geometric mean concentration for fecal coliform data; number of exceedances, number of samples that were equal to or greater than the numeric standard; col/100 mL, colonies per 100 milliliters; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; --, no data]

Parameter	State standard	USGS Data			STORET Data		
		Number of samples	85th percentile	Number of exceedances	Number of samples	85th percentile	Number of exceedances
Gunnison River at Delta (USGS station 09144250, STORET station 000056)							
Fecal coliform (col/100 mL)	200	11	*51	2	146	*37	31
Un-ionized ammonia (mg/L)	.02	13	.002	0	127	.007	2
Sulfate (mg/L)	250	20	300	8	144	240	20
Iron, total (µg/L)	1,000	11	4,200	5	0	--	--
Selenium (µg/L)	5	20	5.5	7	[1]56	3	4
Gunnison River near Grand Junction (USGS station 09152500, STORET station 000054)							
Fecal coliform (col/100 mL)	200	108	*34	24	176	*76	71
Un-ionized ammonia (mg/L)	.02	142	.003	1	144	.014	15
Sulfate (mg/L)	480	337	598	84	62	650	18
Cadmium (µg/L)	3.1	65	2	3	0	--	--
Iron, total (µg/L)	2,300	28	1,900	4	0	--	--
Lead (µg/L)	24	65	6	2	0	--	--
Manganese (µg/L)	50	170	33	9	0	--	--
Selenium (µg/L)	[2]8	132	9	35	[1]58	12	21
Colorado River near Fruita (STORET station 000049)							
Fecal coliform (col/100 mL)	200	0	--	--	68	*632	54
Un-ionized ammonia (mg/L)	.06	0	--	--	46	.017	1
Selenium, total (µg/L)	17	0	--	--	48	9	0
Colorado River at Loma (STORET station 000050)							
Fecal coliform (col/100 mL)	200	0	--	--	413	*178	228
Un-ionized ammonia (mg/L)	.06	0	--	--	421	.011	4
Cadmium (µg/L)	2.9	0	--	--	91	<0.3	0
Iron, total (µg/L)	2,600	0	--	--	6	6,700	2
Selenium, dissolved (µg/L)	17	0	--	--	37	6.9	0
Selenium, total (µg/L)	17	0	--	--	120	11	7
Colorado River near Colorado-Utah State line (USGS station 09163500)							
Fecal coliform (col/100 mL)	200	121	*70	40	0	--	--
Un-ionized ammonia (mg/L)	.06	151	.003	0	0	--	--
Cadmium (µg/L)	2.9	68	3	11	0	--	--
Iron, total (µg/L)	2,600	27	5,900	11	0	--	--
Mercury (µg/L)	.01	67	.1	[3]13	0	--	--
Selenium (µg/L)	17	145	8	1	0	--	--

[1] Data are for total selenium.

[2] Standard is a temporary modification, which expires in August 2002. Eighty-one USGS samples and 32 STORET samples were equal to or greater than 5 µg/L.

[3] Number of samples with mercury concentrations equal to or greater than the 0.1-µg/L minimum reporting level.

Attachment 6--Temperature and Selenium Data: Gunnison River at Whitewater (from Butler 2000 and others)

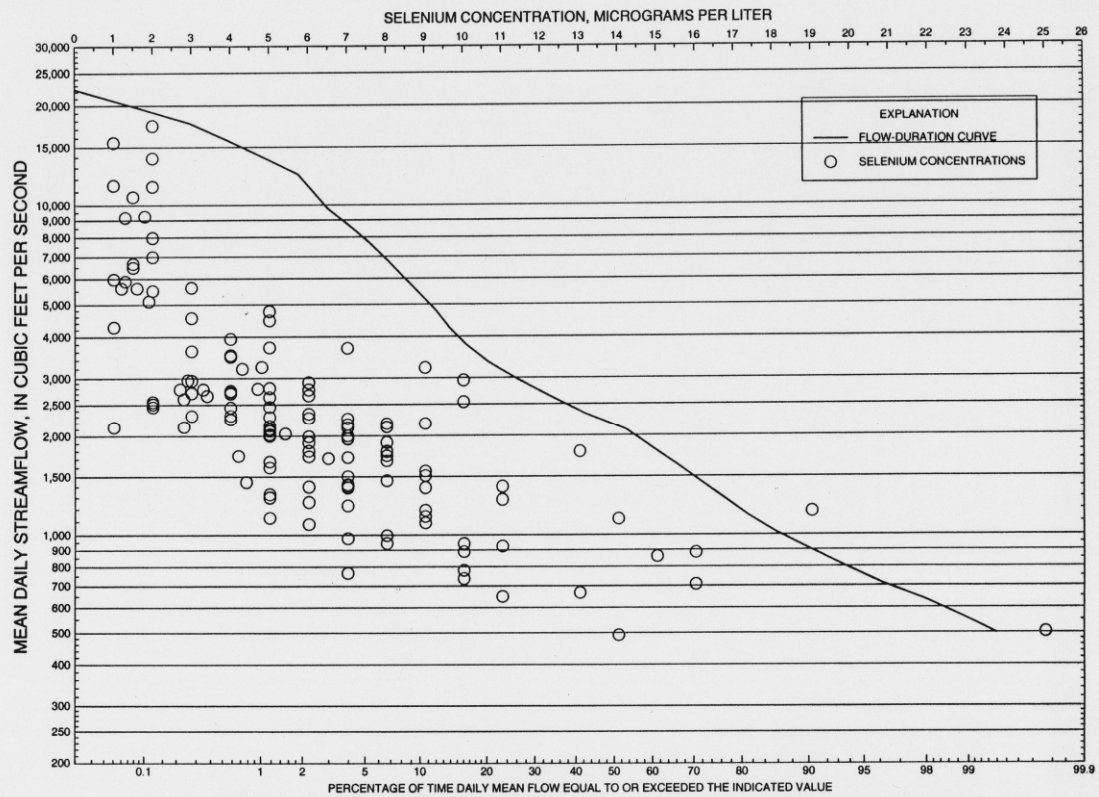

Figure 2. Flow-duration curve and dissolved-selenium concentrations in samples collected by the U.S. Geological Survey since 1976 for station 09152500, Gunnison River near Grand Junction. (132 samples).

Environmental baseline: Average monthly selenium concentration, ppb, Gunnison River at Whitewater.															
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max	Min
1975	17.1	15.5	9.7	5.2	3.7	4.3	6.2	9.8	10.0	10.4	11.1	10.2	9.4	17.1	3.7
1976	11.1	9.6	9.9	7.5	4.9	6.5	9.2	14.1	12.1	11.5	14.3	15.9	10.6	15.9	4.9
1977	13.8	13.7	12.2	12.6	12.2	14.6	16.0	18.4	19.1	17.6	16.8	17.0	15.3	19.1	12.2
1978	15.1	14.7	11.7	4.3	3.3	3.7	7.0	11.5	12.0	17.7	15.2	11.9	10.7	17.7	3.3
1979	7.8	5.3	4.8	3.8	2.7	3.3	6.4	9.4	9.8	10.4	10.4	9.9	7.0	10.4	2.7
1980	9.8	5.3	5.8	4.0	2.4	3.1	7.2	10.9	12.2	15.1	11.0	9.1	8.0	15.1	2.4
1981	11.0	16.8	10.1	7.6	7.5	9.4	11.8	14.0	12.3	10.8	12.7	13.9	11.5	16.8	7.5
1982	8.9	7.5	7.3	4.1	2.7	3.6	6.1	7.5	6.6	6.7	6.8	6.2	6.2	8.9	2.7
1983	7.9	7.4	5.6	4.4	2.4	2.1	3.1	5.8	7.4	6.9	7.0	5.8	5.5	7.9	2.1
1984	4.9	4.6	4.2	3.1	1.9	2.0	3.3	5.8	6.6	6.0	5.8	5.0	4.4	6.6	1.9
1985	4.8	4.8	5.0	2.5	2.0	2.3	4.6	8.4	6.9	6.3	6.2	5.5	4.9	8.4	2.0
1986	5.0	5.7	3.3	2.5	2.2	2.8	3.6	6.9	6.0	5.4	5.2	4.6	4.4	6.9	2.2
1987	5.6	5.3	4.7	2.9	2.4	2.9	6.2	6.6	6.4	7.6	8.1	7.4	5.5	8.1	2.4
1988	8.2	6.7	6.9	4.2	4.6	5.5	7.2	11.1	9.6	10.5	11.6	11.2	8.1	11.6	4.2
1989	8.7	6.7	5.1	3.9	5.2	6.0	7.2	9.9	9.6	10.3	11.1	10.7	7.9	11.1	3.9
1990	10.6	10.0	8.7	7.3	5.3	6.0	7.4	11.1	10.0	9.1	9.5	8.6	8.6	11.1	5.3
1991	8.6	8.2	7.0	4.7	2.8	3.3	5.7	7.0	6.5	6.9	7.1	6.2	6.2	8.6	2.8
1992	7.7	7.8	6.4	3.1	3.0	4.1	5.3	6.8	7.0	6.7	7.0	7.3	6.0	7.8	3.0
1993	7.8	6.1	3.4	2.5	1.6	2.0	4.1	5.6	5.7	5.4	5.7	5.7	4.6	7.8	1.6
1994	6.6	6.3	5.1	4.1	3.1	3.9	6.2	8.2	7.5	6.9	7.2	6.7	6.0	8.2	3.1
1995	7.3	6.9	3.5	2.7	1.8	1.6	2.0	4.6	5.2	5.1	4.8	4.4	4.2	7.3	1.6
1996	5.5	4.0	3.2	2.6	2.2	3.3	5.4	6.9	6.1	6.4	6.0	5.3	4.7	6.9	2.2
1997	4.0	3.5	3.2	2.6	1.8	2.0	3.7	5.0	4.6	4.6	4.7	4.4	3.7	5.0	1.8
1998	5.6	5.3	4.1	2.8	1.9	3.6	4.7	6.8	6.3	6.1	6.2	5.9	4.9	6.8	1.9
1999	6.9	6.2	5.0	5.5	3.0	2.8	4.1	4.4	4.9	5.3	5.4	5.0	4.9	6.9	2.8
2000	5.9	5.2	4.6	3.2	3.5	4.9	5.7	8.4	7.5	7.0	8.1	7.8	6.0	8.4	3.2
2001	7.2	7.3	5.8	4.8	3.1	4.4	5.3	6.7	6.3	6.8	7.4	6.8	6.0	7.4	3.1
2002	7.2	7.3	7.0	6.1	7.0	9.4	10.6	10.4	9.1	8.9	10.3	10.7	8.7	10.7	6.1
2003	9.9	9.0	7.7	6.1	3.6	5.8	11.7	11.1	8.8	9.7	10.5	10.6	8.7	11.7	3.6
2004	9.4	8.7	6.4	3.9	3.6	5.3	6.4	9.6	8.2	8.1	9.5	9.3	7.4	9.6	3.6
2005	6.6	4.6	4.6	2.6	1.9	2.7	4.7	6.8	6.7	6.1	6.9	7.4	5.1	7.4	1.9

Proposed action: Average monthly selenium concentration, ppb, Gunnison River at Whitewater.															
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max	Min
1975	14.1	12.5	11.6	6.1	4.2	4.2	6.7	10.0	10.7	11.1	12.1	11.2	9.5	14.1	4.2
1976	12.0	10.4	10.4	7.8	4.1	7.4	11.5	15.2	14.4	13.1	17.3	17.0	11.7	17.3	4.1
1977	15.3	14.0	13.2	12.7	12.5	13.2	14.3	18.1	19.1	17.6	17.1	17.0	15.4	19.1	12.5
1978	15.2	13.9	11.7	4.7	3.3	3.4	9.2	13.9	13.8	15.5	14.0	12.5	10.9	15.5	3.3
1979	11.5	5.5	6.3	4.1	2.8	2.9	7.2	10.5	13.0	13.1	13.0	12.7	8.5	13.1	2.8
1980	11.3	5.9	6.9	4.5	2.4	3.2	7.3	10.2	12.5	14.3	12.2	10.2	8.4	14.3	2.4
1981	12.1	12.3	10.6	7.9	7.7	9.3	11.7	14.2	12.6	11.0	13.0	14.2	11.4	14.2	7.7
1982	10.9	8.8	8.5	4.3	2.7	3.7	6.5	8.0	7.0	7.1	7.1	6.6	6.8	10.9	2.7
1983	8.5	7.9	5.9	4.5	2.5	2.1	3.2	6.0	7.5	7.1	7.2	6.0	5.7	8.5	2.1
1984	5.0	4.7	4.4	3.1	1.9	2.0	3.5	6.1	6.8	6.1	5.9	5.1	4.5	6.8	1.9
1985	4.9	5.1	5.1	2.6	2.0	2.4	5.0	8.3	7.1	6.4	6.3	5.6	5.1	8.3	2.0
1986	5.2	6.1	3.4	2.7	2.2	2.7	4.4	7.1	6.2	5.5	5.4	4.8	4.6	7.1	2.2
1987	5.9	5.6	4.9	2.9	2.4	3.1	6.3	6.9	6.6	7.9	8.5	7.7	5.7	8.5	2.4
1988	8.8	7.3	7.0	4.4	4.4	5.7	8.0	10.7	10.4	11.6	12.2	12.0	8.5	12.2	4.4
1989	10.3	7.7	5.6	4.0	4.7	6.3	7.8	10.4	10.7	10.6	11.4	11.0	8.4	11.4	4.0
1990	10.7	10.0	8.9	7.4	5.4	6.6	8.4	10.4	10.3	9.3	11.2	11.1	9.2	11.2	5.4
1991	10.3	9.5	8.2	4.8	2.8	3.3	5.9	7.4	6.8	7.2	7.5	6.5	6.7	10.3	2.8
1992	7.9	7.5	6.7	3.3	3.0	4.3	5.4	7.5	7.6	7.1	7.6	8.2	6.3	8.2	3.0
1993	8.2	6.6	3.5	2.8	1.7	1.9	4.2	5.8	5.9	5.6	5.9	5.9	4.8	8.2	1.7
1994	6.8	6.5	5.2	4.2	2.9	4.6	6.4	9.1	8.2	7.5	7.9	7.4	6.4	9.1	2.9
1995	8.0	7.6	3.7	3.0	1.9	1.6	2.0	4.8	5.3	5.2	4.9	4.6	4.4	8.0	1.6
1996	5.6	4.2	3.4	2.9	2.1	3.6	5.6	7.8	6.7	6.9	6.6	5.8	5.1	7.8	2.1
1997	4.0	3.6	3.4	2.6	1.8	2.0	4.2	5.3	4.7	4.7	4.8	4.5	3.8	5.3	1.8
1998	5.8	5.4	4.2	2.9	2.0	3.6	4.8	7.0	6.5	6.2	6.3	6.0	5.1	7.0	2.0
1999	7.5	6.7	5.4	5.6	2.7	2.9	4.5	4.8	5.0	5.6	5.8	5.3	5.2	7.5	2.7
2000	6.2	5.5	4.9	3.3	3.1	5.1	6.8	9.0	8.3	7.8	8.9	9.5	6.5	9.5	3.1
2001	9.2	8.6	7.1	5.0	2.7	5.2	5.5	7.6	7.0	7.6	8.5	8.1	6.8	9.2	2.7
2002	8.0	8.1	7.5	6.4	7.2	8.2	9.1	10.5	9.4	9.1	10.6	10.7	8.7	10.7	6.4
2003	9.7	8.7	7.7	6.2	3.5	5.7	8.1	8.9	9.1	9.9	10.8	10.7	8.2	10.8	3.5
2004	9.4	8.6	6.6	4.0	3.4	6.3	8.1	8.9	8.4	8.3	9.7	9.5	7.6	9.7	3.4
2005	8.1	7.5	6.5	2.9	2.0	2.7	4.8	7.1	7.0	6.3	7.1	7.7	5.8	8.1	2.0

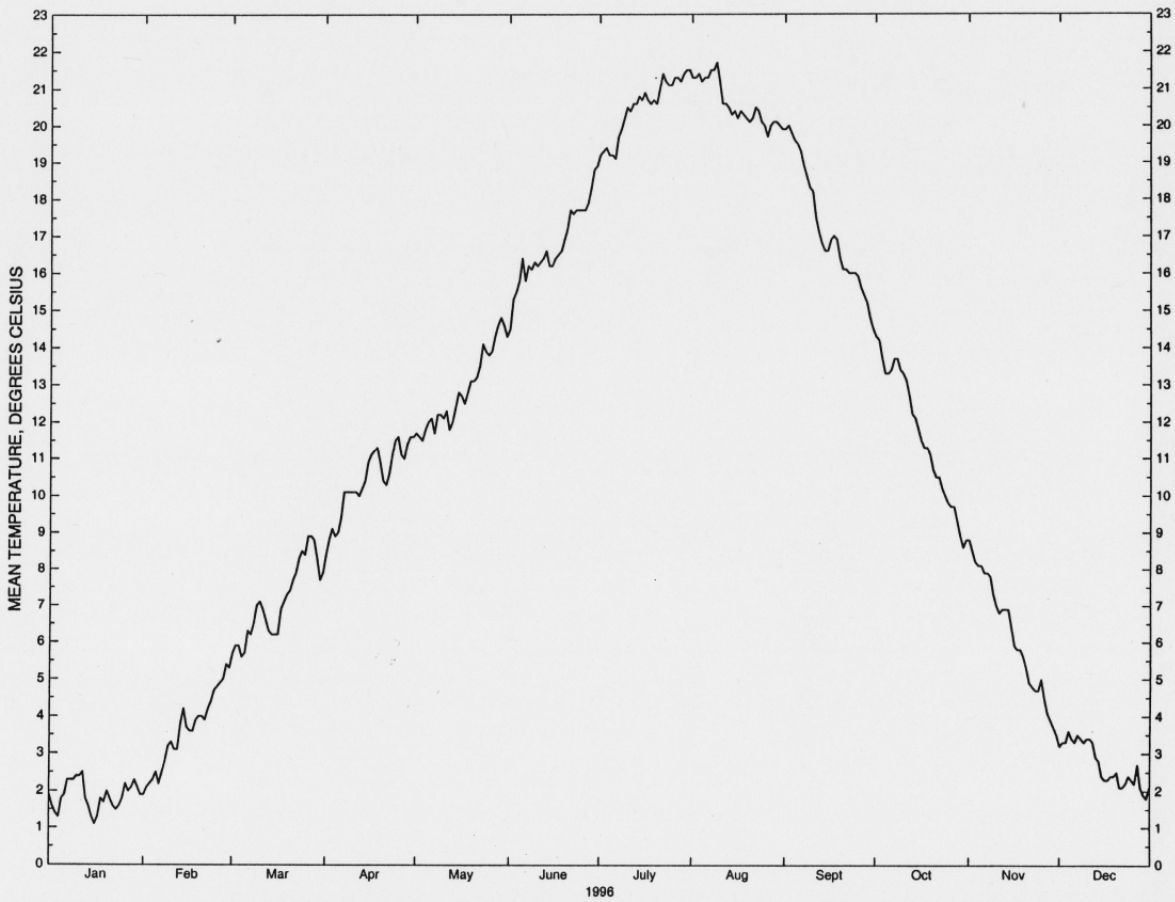

Figure 4. Mean daily water temperature at station 09152500, Gunnison River near Grand Junction, water years 1976-98.

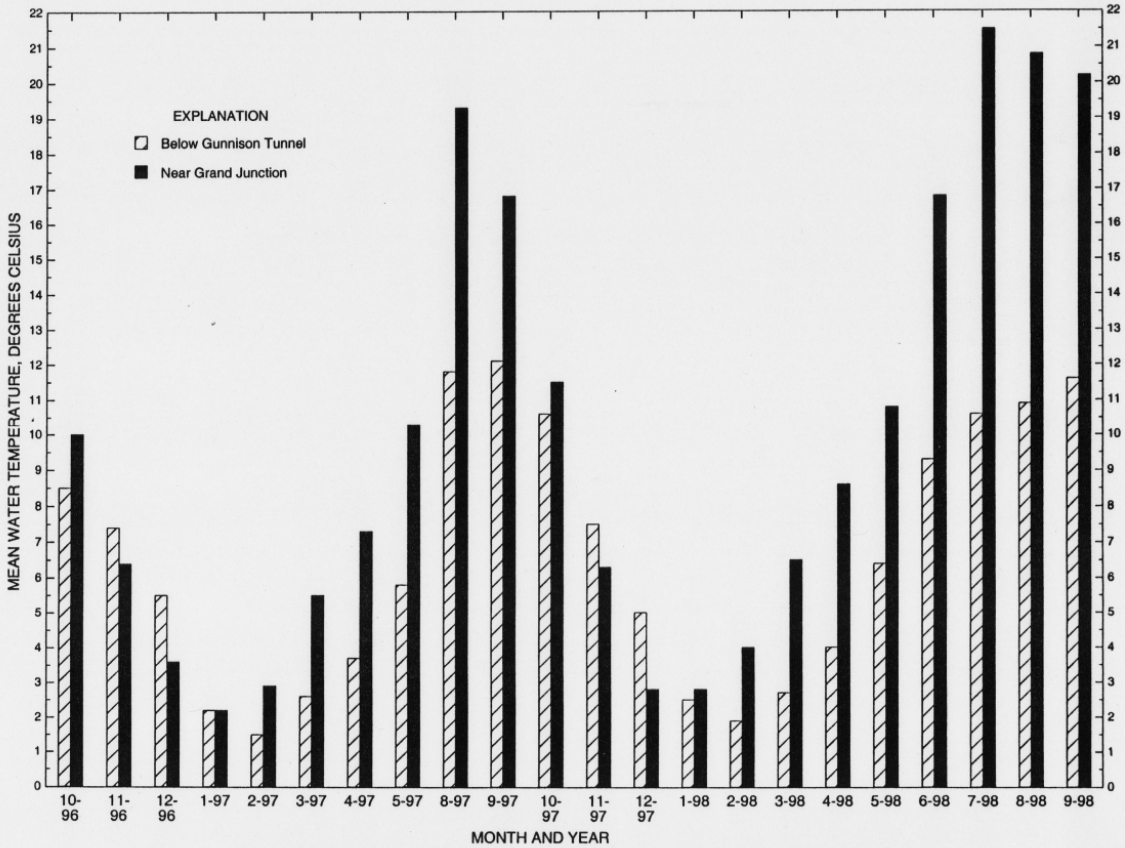

Figure 5. Mean water temperature, by month, Gunnison River below Gunnison Tunnel and Gunnison River near Grand Junction, water years 1997-98. Means computed only using days with values at both sites.

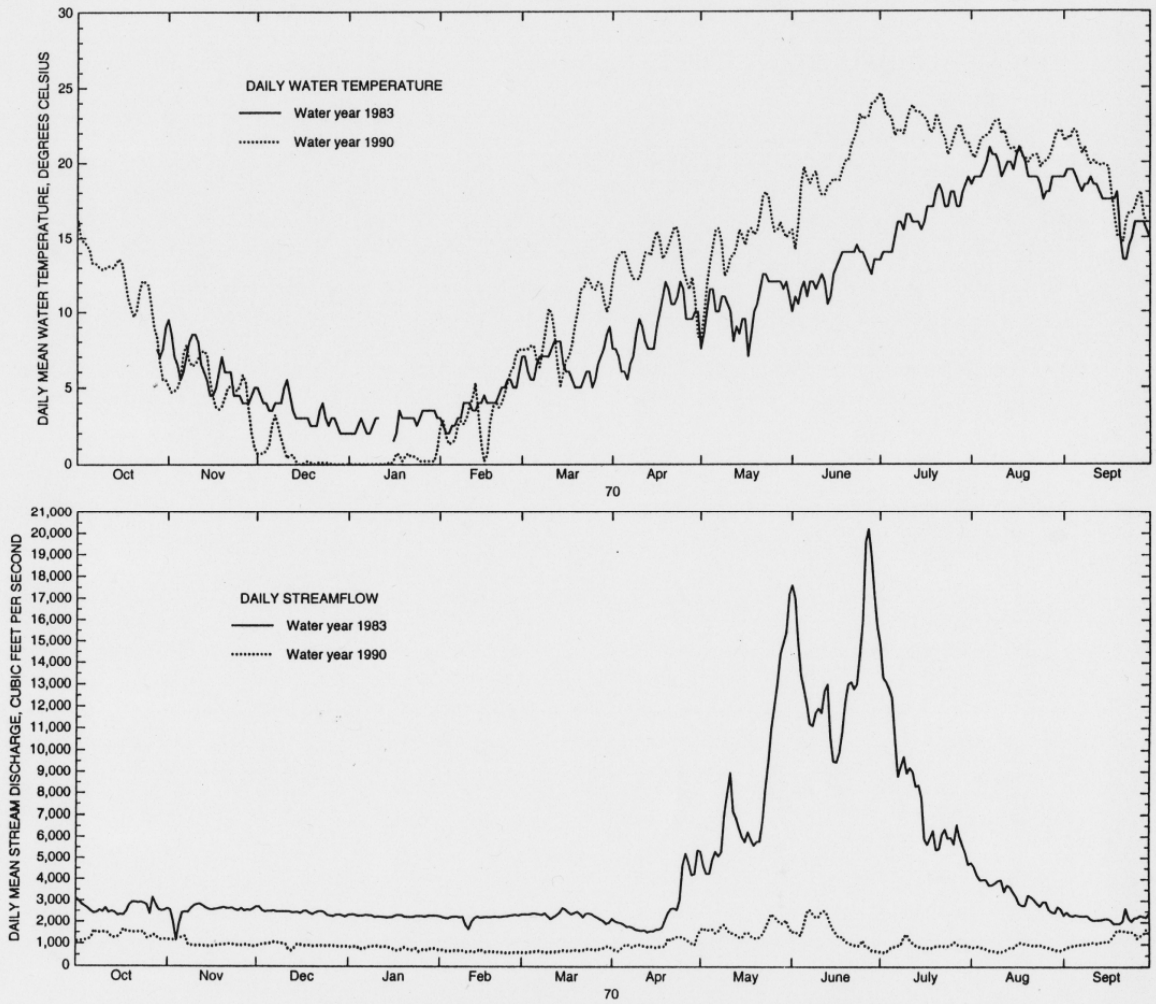

Figure 7. Daily mean stream temperature and streamflow at gaging station 09152500, Gunnison River near Grand Junction, water years 1983 and 1990.

Attachment 7 Recovery Goals [17](from Reclamation 2005)

Recovery Goals-Colorado Pikeminnow (Fish and Wildlife Service 2002c)

Downlisting can be considered if, over a 5-year period:

- A genetically and demographically viable, self-sustaining population is maintained in the Green River subbasin such that (a) the trends in separate adult point estimates for the middle Green River and the lower Green River do not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality for the Green River subbasin, and (c) each population point estimate for the Green River subbasin exceeds 2,600 adults (2,600 is the estimated minimum viable population needed to ensure long-term genetic and demographic viability); and
- A self-sustaining population of at least 700 adults (numbers based on inferences about carrying capacity) is maintained in the upper Colorado River subbasin such that (a) the trend in adult point estimates does not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality; and
- A target number of 1,000 age 5+ fish is established through augmentation and/or natural reproduction in the San Juan River subbasin; and
- Certain site-specific management tasks to minimize or remove threats have been identified, developed, and implemented.

Delisting can be considered if, over a 7-year period beyond downlisting:

- A genetically and demographically viable, self-sustaining population is maintained in the Green River subbasin such that (a) the trends in separate adult point estimates for the middle Green River and the lower Green River do not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality for the Green River subbasin, and (c) each population point estimate for the Green River subbasin exceeds 2,600 adults; and
- Either the upper Colorado River subbasin self-sustaining population exceeds 1,000 adults or the upper Colorado River subbasin self-sustaining population exceeds 700 adults and the San Juan River subbasin population is self-sustaining and exceeds 800 adults (numbers based on inferences about carrying capacity such that or each population (a) the trend in adult point estimated does not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality; and
- Certain site-specific management tasks to minimize or remove threats have been finalized and implemented, and necessary levels of protection are attained.

Recovery Goals-Razorback Sucker (Fish and Wildlife Service 2002d)

Downlisting can be considered if, over a 5-year period:

- Genetically and demographically viable, self-sustaining populations are maintained in the Green River subbasin and either in the upper Colorado River

[17] Recovery goals are being updated.

subbasin or the San Juan River subbasin such that (a) the trend in adult (age 4+) point estimates for each of the two populations does not decline significantly, and (b) mean estimated recruitment of age -3 naturally produced fish equals or exceeds mean annual adult mortality for each of the tow populations, and)c) each point estimate for each of the two populations exceeds 5,800 adults (5,800 is the estimated minimum viable population needed to ensure long-term genetic and demographic viability); and

- A genetic refuge is maintained in Lake Mohave of the lower basin recovery unit; and
- Certain site-specific management tasks to minimize or remove threats have been identified, developed, and implemented.

Delisting can be considered if, over a 3-year period beyond downlisting:

- Genetically and demographically viable, self-sustaining populations are maintained in the Green River subbasin and either in the upper Colorado River subbasin or the San Juan River subbasin such that (a) the trend in adult point estimates for each of the two populations does not decline significantly, and (b) mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each of the two populations, and (c) each point estimate for each of the two populations exceeds 5,800 adults; and
- A genetic refuge is maintained in Lake Mohave; and
- Two genetically and demographically viable, self-sustaining populations are maintained in the lower basin recovery unit such that (a) the trend in adult point estimates for each population does not decline significantly, and (b) mean estimated recruitment of age-3 naturally produced fish equals or exceed mean annual adult mortality for each population, and (c) each point estimate for each population exceeds 5,800 adults; and
- Certain site-specific management tasks to minimize or remove threats have been finalized and implemented, and necessary levels of protection are maintained.

Recovery Goals-Humpback Chub (Fish and Wildlife Service 2002e)

Downlisting can be considered if, over a 5-year period:

- The trend in adult (age 4+) point estimates for each of the six extant populations does not decline significantly; and
- Mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each of the six extant populations; and
- Two genetically and demographically viable, self-sustaining core populations are maintained, such that each point estimate for each core population exceeds 2,100 adults (2,100 is the estimated minimum viable population needed to ensure long-term genetic and demographic viability); and
- Certain site-specific management tasks to minimize or remove threats have been identified, developed, and implemented.

Delisting can be considered if, over a 3-year period beyond downlisting:

- The trend in adult point estimates for each of the six extant populations does not decline significantly; and
- Mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each of the six extant populations; and

- Three genetically and demographically viable, self-sustaining core populations are maintained, such that each point estimate for each core population exceeds 2,100 adults; and
- Certain site-specific management tasks to minimize or remove threats have been finalized and implemented, and necessary levels of protection are attained.

Management actions identified in the recovery goals for bonytail (Fish and Wildlife Service 2002) to minimize or remove threats to the species include:

- Provide and legally protect habitat (including flow regimes necessary to restore and maintain required environmental conditions) necessary to provide adequate habitat and sufficient range for all life stages to support recovered populations;
- Provide passage over barriers within occupied habitat to allow unimpeded movement and, potentially, range expansion;
- Investigate options for providing appropriate water temperatures in the Gunnison River;
- Minimize entrainment of subadults and adults and diversion/take-out structures;
- Investigate habitat requirement s for all life stages and provide those habitats;
- Ensure adequate protection from overutilization;
- Ensure adequate protection from diseases and parasites; regulate nonnative fish releases and escapement in the main river, floodplain, and tributaries;
- Control problematic nonnative fishes as needed;
- Minimize the risk of increased hybridization among *Gila* spp.;
- Minimize the risk of hazardous-materials spills in critical habitat; and
- Remediate water-quality problems.

Attachment 8--Additional hydrology data

8.1 Summary of peaks (cfs) under baseline and proposed alternative, Whitewater gage.

Year	Baseline Peak	Proposed Action Peak	Year	Baseline Peak	Proposed Action Peak
1975	8927	12296	1991	8412	8593
1976	5130	8386	1992	6063	8583
1977	1581	1636	1993	20492	21040
1978	10678	11364	1994	4919	7755
1979	15164	16261	1995	19346	19125
1980	13884	16326	1996	7860	12412
1981	3773	3771	1997	11996	14350
1982	9140	11023	1998	9877	9158
1983	20640	20350	1999	6793	7783
1984	20782	20941	2000	4817	7840
1985	15186	15503	2001	3487	7439
1986	10357	13727	2002	1153	1170
1987	9241	10191	2003	5312	7033
1988	3436	5814	2004	3413	5207
1989	2465	5243	2005	13574	11372
1990	2574	2566			

8.2 Comparison of flow duration under baseline and proposed action at Whitewater gage.

Year	Days >6,000 cfs		Days>7,000 cfs		Days>8,000 cfs		Days>10,000 cfs		Days>14,000 cfs	
	Baseline	Plan	Baseline	Plan	Baseline	Plan	Baseline	Plan	Baseline	Plan
1975	32	37	26	33	8	24	0	6	0	0
1976	0	11	0	8	0	2	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0
1978	27	42	15	36	11	25	2	9	0	0
1979	53	57	35	44	27	34	16	22	4	5
1980	61	55	50	45	42	36	13	17	0	3
1981	0	0	0	0	0	0	0	0	0	0
1982	26	32	16	23	9	15	0	6	0	0
1983	75	71	59	67	53	54	44	44	13	17
1984	85	87	78	77	67	67	57	56	31	30
1985	81	81	75	73	62	57	29	31	4	6
1986	63	59	40	44	25	28	5	17	0	0
1987	42	43	34	34	18	17	0	1	0	0
1988	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0
1991	9	13	4	9	1	2	0	0	0	0
1992	1	5	0	3	0	1	0	0	0	0
1993	75	64	66	58	49	50	27	35	17	18
1994	0	7	0	4	0	0	0	0	0	0
1995	93	82	76	74	73	72	61	69	28	29
1996	10	23	7	20	0	9	0	4	0	0
1997	67	64	53	50	47	37	12	15	0	2
1998	30	29	18	14	7	6	0	0	0	0
1999	7	14	0	11	0	0	0	0	0	0
2000	0	7	0	3	0	0	0	0	0	0
2001	0	7	0	3	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0
2003	0	3	0	1	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0
2005	31	26	19	17	12	10	7	5	0	0
Average	28.0	29.6	21.6	24.2	16.5	17.6	8.8	10.9	3.1	3.5

8.3 Days reaching various flow levels important to backwater/flooded bottomland habitat.

Year	Days >5,000 cfs*		Days >8,000 cfs*		Days >10,000 cfs*		Days >14,000 cfs*	
	Baseline	Plan	Baseline	Plan	Baseline	Plan	Baseline	Plan
1975	41	39	85	24	0	6	0	0
1976	2	13	0	2	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	44	44	118	25	2	9	0	0
1979	65	75	27	34	16	22	4	5
1980	67	67	42	36	13	17	0	3
1981	0	0	0	0	0	0	0	0
1982	38	43	9	15	0	6	0	0
1983	92	91	53	54	44	44	13	17
1984	94	95	66	67	57	56	31	30
1985	84	82	62	57	29	31	4	6
1986	101	77	25	28	5	17	0	0
1987	60	59	18	17	1	1	0	0
1988	0	3	0	0	0	0	0	0
1989	0	2	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0
1991	26	24	1	2	0	0	0	0
1992	2	8	0	1	0	0	0	0
1993	80	73	49	50	27	35	17	18
1994	0	11	0	0	0	0	0	0
1995	94	88	73	72	61	69	28	29
1996	28	27	0	9	0	4	0	0
1997	76	75	47	37	12	15	0	2
1998	40	40	7	6	0	0	0	0
1999	12	17	0	0	0	0	0	0
2000	0	10	0	0	0	0	0	0
2001	0	10	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0
2003	2	9	0	0	0	0	0	0
2004	0	1	0	0	0	0	0	0
2005	48	41	12	10	7	5	0	0
Avg. days/yr	35.4	36.3	16.5	17.6	8.8	10.9	3.1	3.5
Percentage of years	68	87	48	61	32	48	10	26

8.4 Number of cross-sections reaching ½ bankfull or bankfull during May-July

Year	Baseline-No. cross-sections reaching ½ bankfull	Proposed Action-No. cross-sections reaching ½ bankfull	Baseline-No. cross-sections reaching bankfull	Proposed Action-No. cross-sections reaching bankfull
1975	36	52	2	14
1976	5	30	0	1
1977	0	0	0	0
1978	45	47	4	7
1979	54	54	33	38
1980	54	54	25	38
1981	0	0	0	0
1982	37	46	2	7
1983	54	54	44	44
1984	54	54	44	44
1985	54	54	33	33
1986	45	54	4	24
1987	38	44	2	3
1988	0	9	0	0
1989	0	6	0	0
1990	0	0	0	0
1991	31	33	1	1
1992	11	33	0	1
1993	54	54	44	44
1994	3	24	0	1
1995	54	54	15	43
1996	24	52	1	14
1997	51	54	14	31
1998	44	38	3	2
1999	0	24	0	1
2000	2	24	0	0
2001	0	23	0	0
2002	0	0	0	0
2003	6	19	0	0
2004	0	6	0	0
2005	54	47	23	7
	Avg 26	Avg 37	Avg 9	Avg 13
Percentage of years ½ or bankfull flows reached	71%	87%	55%	68%

Attachment 8.5. Comparison of Baseline and Proposed Operation, number of days in the year above given flow, presented according to year category.

Year	Water category	**Base >5000 cfs**	**Action >5000 cfs**	Base >7000 cfs	Action >7000 cfs	**Base >8000 cfs**	**Action >8000 cfs**	Base >10000 cfs	Action >10000 cfs	**Base >14000 cfs**	**Action >14000 cfs**
1977	Dry	**0**	**0**	0	0	**0**	**0**	0	0	**0**	**0**
1981	Dry	**0**	**0**	0	0	**0**	**0**	0	0	**0**	**0**
2002	Dry	**0**	**0**	0	0	**0**	**0**	0	0	**0**	**0**
1990	Dry	**0**	**0**	0	0	**0**	**0**	0	0	**0**	**0**
1988	ModDry	**0**	**3**	0	0	**0**	**0**	0	0	**0**	**0**
1989	ModDry	**0**	**2**	0	0	**0**	**0**	0	0	**0**	**0**
1992	ModDry	**2**	**8**	0	3	**0**	**1**	0	0	**0**	**0**
1994	ModDry	**0**	**11**	0	4	**0**	**0**	0	0	**0**	**0**
2000	ModDry	**0**	**10**	0	3	**0**	**0**	0	0	**0**	**0**
2001	ModDry	**0**	**10**	0	3	**0**	**0**	0	0	**0**	**0**
2003	ModDry	**2**	**9**	0	1	**0**	**0**	0	0	**0**	**0**
2004	ModDry	**0**	**1**	0	0	**0**	**0**	0	0	**0**	**0**
1976	AvgDry	**2**	**13**	0	8	**0**	**2**	0	0	**0**	**0**
1987	AvgDry	**60**	**59**	34	34	**18**	**17**	0	1	**0**	**0**
1991	AvgDry	**26**	**24**	4	9	**1**	**2**	0	0	**0**	**0**
1998	AvgDry	**40**	**40**	18	14	**7**	**6**	0	0	**0**	**0**
1999	AvgDry	**12**	**17**	0	11	**0**	**0**	0	0	**0**	**0**
1982	AvgWet	**38**	**43**	16	23	**9**	**15**	0	6	**0**	**0**
1983	AvgWet	**92**	**91**	59	67	**53**	**54**	44	44	**13**	**17**
1996	AvgWet	**28**	**27**	7	20	**0**	**9**	0	4	**0**	**0**
2005	AvgWet	**48**	**41**	19	17	**12**	**10**	7	5	**0**	**0**
1975	ModWet	**41**	**39**	26	33	**8**	**24**	0	6	**0**	**0**
1978	ModWet	**44**	**44**	15	36	**11**	**25**	2	9	**0**	**0**
1979	ModWet	**65**	**75**	35	44	**27**	**34**	16	22	**4**	**5**
1980	ModWet	**67**	**67**	50	45	**42**	**36**	13	17	**0**	**3**
1985	ModWet	**84**	**82**	75	73	**62**	**57**	29	31	**4**	**6**
1986	ModWet	**101**	**77**	40	44	**25**	**28**	5	17	**0**	**0**
1993	ModWet	**80**	**73**	66	58	**49**	**50**	27	35	**17**	**18**
1995	ModWet	**94**	**88**	76	74	**73**	**72**	61	69	**28**	**29**
1997	ModWet	**76**	**75**	53	50	**47**	**37**	12	15	**0**	**2**
1984	Wet	**94**	**95**	78	77	**67**	**67**	57	56	**31**	**30**
Avg.		**35.4**	**36.3**	21.6	24.2	**16.5**	**17.6**	8.8	10.9	**3.1**	**3.5**

Attachment 9. Flow changes (on peak day of Gunnison River in May) in Colorado River downstream from the Gunnison River for period of study with proposed plan

Year	May change (cfs) on Gunnison River peak day	Year	May change (cfs) on Gunnison River peak day
1975	+3369	1991	+181
1976	+3256	1992	+2520
1977	-11	1993	+548
1978	+686	1994	+2836
1979	+1097	1995	+2722
1980	+2442	1996	+4552
1981	-2	1997	+2534
1982	+1883	1998	-719
1983	-748	1999	+3644
1984	-21	2000	+3023
1985	+1179	2001	+3952
1986	+2874	2002	+17
1987	+482	2003	+1721
1988	+2378	2004	+1794
1989	+2778	2005	-2207
1990	-3		

Predicted and potential changes in flow as result of proposed action, Colorado River, Colorado-Utah stateline.

Year	Historic peak (cfs)	Potential change in peak (cfs)	Historic avg. monthly flow in May	Predicted change in avg. monthly flow in May	Historic avg. monthly flow in June	Predicted change in avg. monthly flow in June
1975	26,300	+3369	13,150	+301	18,710	+861
1976	14,400	+3256	8,843	+1754	8,881	-191
1977	5,080	-11	2,283	+33	2,688	+118
1978	27,800	+686	11,540	+639	19,690	+1376
1979	36,000	+1097	18,650	-237	22,760	+2143
1980	32,100	+2442	20,300	+357	22,290	+259
1981	12,100	-2	4,600	-3	6,516	+30
1982	19,300	+1883	12,340	+500	16,370	+409
1983	62,100	-748	17,540	-34	41,400	+383
1984	69,800	-21	37,960	-3	43,120	-23
1985	39,300	+1179	28,570	+494	25,280	-135
1986	33,800	+2874	22,370	+246	24,070	+1585
1987	22,500	+482	15,520	+276	11,080	-167
1988	15,400	+2378	8,551	+461	9,108	-52
1989	9,970	+2778	6,651	+703	6,234	-59
1990	12,600	-3	4,078	-3	7,131	-496
1991	19,800	+181	10,610	+293	14,320	-27
1992	16,500	+2520	10,170	+418	7,415	+15
1993	44,300	+548	27,350	-573	25,390	+1293
1994	13,600	+2836	9,912	+969	7,857	-601
1995	49,300	+2722	15,040	+493	33,590	+28
1996	29,100	+4552	18,460	+1275	17,620	+166
1997	37,500	+2534	22,500	+566	29,980	+456
1998	26,100	-719	18,470	-178	12,450	-71
1999	17,900	+3644	9,775	+1178	15,190	-118
2000	17,900	+3023	10,940	+1108	8,640	+359
2001	13,200	+3952	9,017	+1353	6,310	-473
2002	5,520	+17	2,640	-1	2.431	-42
2003	26,100	+1721	9,043	+459	10,100	+16
2004	9,450	+1794	6,615	+459	5,309	-230
2005	31,000	-2207	16,110	-909	15,750	-42

Attachment 10—Redlands, Gunnison River below Redlands Diversion, comparison of days with flows less than 300 cfs and less than 100 cfs in the April through September period

Year	Baseline <300	Plan <300	Baseline <100	Plan <100
1975	0	0	0	0
1976	16	42	0	2
1977	176	179	18	27
1978	0	47	0	0
1979	0	10	0	0
1980	7	9	2	3
1981	8	106	20	24
1982	0	8	0	0
1983	0	0	0	0
1984	0	0	0	0
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	34	47	5	4
1989	16	46	0	1
1990	64	96	17	12
1991	0	1	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	0	21	0	0
1995	0	0	0	0
1996	0	3	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	11	15	4	5
2000	13	31	0	4
2001	1	17	0	0
2002	140	164	16	28
2003	100	89	8	16
2004	32	75	9	9
2005	0	1	0	0
Avg days	22.3	32.2	3.2	4.4

Attachment 11--Additional guidelines for Aspinall Unit operations included in proposed action

- Aspinall Unit in place, regulating the river and operating for authorized Unit purposes under a wide range of annual inflow conditions.

- At the beginning of the year, water would be released using the most recent January through March inflow forecast and downstream water demands with the goal of achieving a March 31st Blue Mesa Reservoir content target (determined from the January, February, and March 1st forecasted April-July Blue Mesa inflow) and with a goal of higher releases during January for power purposes. The March 31st target is intended to optimize Aspinall Unit storage, flood control, and hydropower production. (Note: The first April through July forecast is received on January 1, after which they are received twice a month through July.) Filling Blue Mesa Reservoir by the end of runoff season is a general goal. Maximum capacity is reached at 7519.4 feet; however, operations are designed to fill to a lesser level to provide a safety factor for controlling the reservoir in case of sudden high inflow due to thunderstorms or high rate of snowmelt.

- Operations will meet at least 300 cfs in the Black Canyon and Gunnison Gorge except in certain cases of significant drought (e.g. as determined by reservoir elevation projections) or emergencies when flows may be reduced to 200 cfs as measured at the USGS Gage below the Gunnison Tunnel. Such a decision will be made only after coordinating with the State of Colorado and other interested/affected parties.

- The Corps of Engineer's flood control manual requires that efforts are made to keep flows below 15,000 cfs. Existing spring flood control operations would be continued using discretion and coordinating with the city and county of Delta in an effort to maintain flows below levels which may cause damage.

- Significant Gunnison Gorge flow decreases that could damage redds from October 15th through May for brown trout recruitment would be avoided when practical. Flow decreases would be avoided after April 15th for rainbow trout spawning when practical. Flow decreases can lead to dewatering or ice damage to eggs.

- Blue Mesa winter icing elevation target, 7490 feet or lower at end of December, will be operated for to reduce chances of ice jams causing upstream flooding in the Gunnison area, for example in the Dos Rios subdivision area.

- The potential exists for modifications to operations under the alternatives as a result of extreme hydrologic conditions, emergencies, or unforeseen conditions. Operational changes in severe or extended droughts could include temporary modifications to any given operation plan for the reservoir and potential short-term modifications to the target flows in the Flow Recommendations. In periods of extreme, multi-year droughts, releases from the Aspinall Unit may have to be reduced to match the inflow to the reservoir during part of the year.

  Operations may be modified due to special maintenance or replacement needs at the Aspinall Unit which may limit outlet capacities or require special downstream flows for repairs and inspections. Special flows may also be needed at some time in the future for repairs or replacement of the Gunnison Tunnel Diversion Dam.

  Emergencies may be associated with dam safety, safety of individuals and groups associated with recreation or other activities on the river, or power system conditions. Emergencies associated with dam safety could require unforeseen releases or operations to protect dam structures. Emergencies related to the safety of individuals may be associated with river rescue or recovery operations. Power emergencies could include insufficient short-term generation capacity, transmission maintenance, and other factors. Emergency power operations are typically of short durations as a result of emergencies occurring at the dam or within the transmission network.

  In the case of emergencies, Reclamation will take appropriate actions immediately and then contact the Service in as timely manner as practical for advice on measures to minimize the effects; and formal consultation, if needed, will be conducted after the fact.

- Peaking power operations conducted at Morrow Point and Blue Mesa will continue with flows downstream from Crystal regulated through constant releases to offset impacts of peaking operations upstream. Blue Mesa power releases will range from 0 to 3,400 cfs and Morrow Point power releases from 0 to 5,000 cfs. During Crystal spills, Morrow Point peaking releases may be reduced to avoid large daily fluctuations downstream from Crystal.

- Alternatives will continue to meet power system requirements of the North American Electrical Reliability Council and the Western Electricity Coordinating Council such as generation control, voltage regulation, black start capability, and reserves. For example, Unit operations--such as Morrow Point peaking—are used in emergency situations to prevent major power problems in the West. Existing power contracts from the Unit would be included (note that CRSP power contracts are not “unit specific” but apply to integrated project facilities). Reclamation will continue to

assist Western Area Power Administration (Western) in meeting contract needs while following relevant laws and regulations and the Reclamation/Western MOU.

- The Black Canyon of the Gunnison National Park reserved water right exists but is not quantified. Expected to be quantified but details not determined.

- Morrow Point and Crystal Reservoirs' daily fluctuations will be limited by landslide criteria.

- The Unit will be operated subject to water laws and water rights as decreed under Colorado water law and the Law of the River

- Alternatives honor existing contracts and agreements, including water sales from the Aspinall Unit.

- Existing depletions in the Gunnison River basin from private and public water rights under Colorado law (including evaporation, diversions, transpiration, etc) will continue. Reasonably foreseeable future depletions, based on input from water user representatives, will be included:
    - Assume 3,500 acre-feet (af) of additional depletion in the North Fork area
    - Assume full depletion of Dallas Creek Project water in the Uncompahgre Basin (17,200 af)
    - Assume 8,600 af presently being used under the Upper Gunnison Subordination Agreement
    - Assume additional 22,000 af of future depletion under the Upper Gunnison Subordination Agreement—total depletion under agreement would be 30,800 af in foreseeable future. Ultimate use of full 60,000 af assumed.
    - Assume full depletions of the Dolores Project occurring.

- The proposed action also recognizes that one of the purposes of the Aspinall Unit is "…storing water for beneficial consumptive use, making it possible for the States of the Upper Basin to utilize, consistently with the provisions of the Colorado River Compact, the apportionments made to and among them in the Colorado River Compact and the Upper Colorado River Compact, respectively…". This use is compatible with the Recovery Program which has a goal of fish recovery and water development.

  Remaining project yield" (not precisely known, but up to approximately 300,000 af, minus subordination water use and existing water contracts)

will continue to be stored or go downstream and be modeled as such. It is recognized that this remaining water may be developed in the future pursuant to the Colorado River and Upper Colorado River Basin Compacts, and subject to and consistent with the Unit's authorized purposes and other applicable laws. The State of Colorado has consumptive use depletions remaining for use under the Colorado River Compact of 1922 and the Upper Colorado River Basin Compact and a portion of this would legally be available for development using sources in the Gunnison Basin. The unused portion of the Unit yield would not be reserved permanently for flow recommendations. In the EIS, the potential use of the remaining yield is not included in alternatives because specific foreseeable proposals are not available, so that the unused portion of the Unit's yield would be available for meeting the flow recommendations under the alternatives. Alternatives recognize that consumptive use up to a total of 300,000 af of yield may occur in the future under Colorado's compact entitlements. When future water sales or uses of portions of the "remaining project yield" from the Unit are proposed, the proposals will be evaluated under NEPA. If Reclamation determines the proposed sale or use may affect a listed species, formal ESA consultation will commence. If the Upper Colorado River Basin Recovery Implementation Program (UCRIP) has made sufficient progress implementing the Recovery Action Plan, then the UCRIP may serve as reasonable and prudent measures or reasonable and prudent alternatives, as appropriate. The Section 7 Consultation, Sufficient Progress, and Historic Projects Agreement for the UCRIP as revised in 2000 provides information on ESA compliance for future projects, such as use of Aspinall Unit yield.

- Alternatives will include Taylor Park 1975 and 1990 agreements and Taylor Park refill right in place. Aspinall Unit will be operated to protect Uncompahgre Project water stored in Blue Mesa under the Taylor Park Exchange Agreement. The Uncompahgre Project's Gunnison Tunnel and Dallas Creek Project's Ridgway Reservoir exchange will continue in place.

- Operation meetings will be held 3 times per year to discuss operation plans for the Unit.

Attachment 12—Hydrology Modeling

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 historic stream flows. Outflows consist of water flowing across the downstream basin boundary (Gunnison River at the confluence with the Colorado River at Grand Junction), Gunnison Tunnel diversions, Redlands Power Canal diversions, and consumptive use (crops, domestic use, natural vegetation, evaporation, etc.). Water storage consists of the water within basin reservoirs. In the Gunnison River model only unnatural (man-induced) hydrologic effects are explicitly modeled. The model uses with the historic inflows and 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 on natural vegetation, consumptive use by natural vegetation, runoff of excess precipitation, evaporation from the free water surfaces of rivers, etc. is assumed to be reflected in the inflows. Therefore reach gains and losses are 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 Gunnison River Basin consist of the historic inflows, stream reach gains. The outflows consist of the man-affected (gaged) flow of the Gunnison River at the confluence with the Colorado River, depletions including consumptive irrigation, domestic use and net (in excess of natural) evaporation from manmade reservoirs.. The change in storage is reflected in the difference between beginning and ending reservoir content. The effects of soil water storage for irrigated lands are incorporated into the historical streamflow and stream reach gains and losses and are not explicitly modeled. The RiverWare model of the Gunnison River Basin operates on a daily time-step, simulating the flow at every gaging station. The model separates reservoir operations into 3 time periods: January-March, April-July, and August-December. Basic daily inputs to the model are: historic Blue Mesa inflows, both actual and unregulated; historic side inflows to Morrow Point and Crystal; Gunnison Tunnel diversion; and various downstream gains computed from actual gage data. Other data provided as input to the model includes forecasted inflow and tunnel demands for each forecast period.

Forecast data, both reservoir inflow and tunnel demand, is for the current forecast period and can be input on any day; generally on the first day of the month and then on the fifteenth if available. Forecast data for the last month of the forecast period generally has to be adjusted (sometimes daily) to reflect the improved accuracy which occurs at the end of the forecast period. The model determines remaining forecasted inflow and demand by subtracting the inflows or demands to date from the most recent forecast data available. Remaining minimum canyon demands, which include trout spawning and incubation flows, are computed at various times in the model since these demands are dependent upon flows that occur during the model run.

Based on forecasted inflows, forecasted demands (Gunnison Tunnel and Black Canyon requirements), and storage or release of storage, a volume of water that should be released before the end of the forecast period is determined. This volume is generally referred to as the operation volume. Operation volume is converted to a daily flow rate (cfs) and added to the required downstream releases to compute the desired total release. Actual releases equal this desired release unless policy or physical constraints are triggered. Required downstream releases include tunnel diversion and canyon requirements. Canyon requirements include a minimum flow of 300 cfs and the flow needed to minimize impacts to the spawning and incubation of brown and rainbow trout.

Constraints which may be applied to the computed release include ramping rates in the Black Canyon, flood control decisions both at Blue Mesa and Delta, and powerplant limitations.

At Blue Mesa, the daily release is set to be "Canyon Requirement + Gunnison Tunnel Demand-Side Inflow to Crystal and Morrow Point + Crystal Operation Release". Blue Mesa daily release may be reset by other constraints:

-If the desired Blue Mesa release results in Blue Mesa exceeding its maximum content, release is increased.
-Blue Mesa release is reduced if flow at Delta exceeded 14,000 cfs on the previous day.
-Blue Mesa release adjusted if ramping rates (either up or down) in the canyon are exceeded.
-Blue Mesa release is increased if the minimum brown or rainbow trout spawning or incubation flow, or the minimum canyon flow of 300 cfs is not met. (can occur due to tunnel diversions changing.)
-During Jan-Mar release are limited so that all releases at Crystal go through the powerplant.
-Blue Mesa release will be increased, subject to downstream ramping criteria, if with the current rate of fill, Blue Mesa would have less than 2 feet of storage space remaining at the end of 9 days. Release is the minimum of 6,000 cfs or the release which would result in having 2 feet of storage space remaining.
-If high fall releases are anticipated, June and July flows may be increased. This provides for additional power generation and more stable canyon flows.

In general, Crystal Reservoir release is equal to the Blue Mesa release plus side inflows occurring between Blue Mesa and Crystal.

Operation of the Aspinall Unit to provide peak flows at Whitewater also requires forecasting the time of peak runoff for the North Fork of the Gunnison River, in an attempt to allow releases from Crystal Dam to match the North Fork's peak. The required timing of the peak release from Crystal Reservoir was adjusted to closely approximate the timing of the North Fork peak, occurring during the last two weeks in May, with the assumption that this level of accuracy in predicting

the peak could be reproduced in future operations. For the proposed action modeling, releases to attempt to reach the peak target are made for up to 9 days.

The model in its present configuration represents the best science available to assess the impacts of baseline and proposed operations on various the endangered fish of the Gunnison River.

Appendix C

Methodology for Analyzing the Impacts of Aspinall EIS Alternatives on Power Economics

Methodology for Analyzing the Impacts of Aspinall EIS Alternatives on Power Economics

August, 2008

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Prepared for the Bureau of Reclamation

Introduction

The Western Area Power Administration's (Western) Colorado River Storage Project (CRSP) Management Center markets CRSP power resources as well as the hydroelectric power plants of the Collbran and Rio Grande projects. The energy and capacity from these projects, collectively referred to as the Salt Lake City Area Integrated Projects (SLCA/IP), are marketed to more than 140 customers in six western states on both a long-term and short-term firm basis. Electricity produced by SLCA/IP resources also serves the energy requirements of specific project uses, such as irrigation. When energy production exceeds firm contractual obligations, the excess electricity is sold on the spot market. In addition, SLCA/IP hydropower plants provide the grid with ancillary services including regulation and spinning reserves. In support of an Environmental Impact Statement (EIS), this document focuses on the methods that were developed for evaluating the economics of a cascade of three CRSP hydropower plants: Crystal, Blue Mesa, and Morrow Point. Located on the Gunnison River, these hydropower plants and their associated reservoirs are collectively referred to as the Aspinall Cascade.

Aspinall Storage and Power Characteristics

The Aspinall Cascade is a part of the CRSP authorized by a Congressional Act of April 11, 1956, under Public Law 485, 84th Congress, 70 Stat. 105. As shown on the map in Figure 1, the Aspinall Cascade is located along a 40-mile section of the Gunnison River between the towns of Gunnison and Montrose, Colorado. The Blue Mesa Dam and hydropower plant is at the top (i.e., highest elevation level) of the cascade, followed by Morrow Point and then Crystal. Water storage capacities, in terms thousand-acre-feet (TAF) for these three reservoirs are shown in Figure 2. The Blue Mesa reservoir has the

largest water storage capacity which is more than 8 times larger than the Morrow Point reservoir and more than 36 times larger than the Crystal.

The secondary y-axis of Figure 2 shows power plant generating nameplate capacity in terms of Mega-watt (MW). The cascade has a total generating capacity of 291.7 MW with the Morrow Point power plant having the largest generating capacity at 173.3 MW. The Blue Mesa's power plant capacity is about one-half as large followed by Crystal with a capacity of 32 MW.

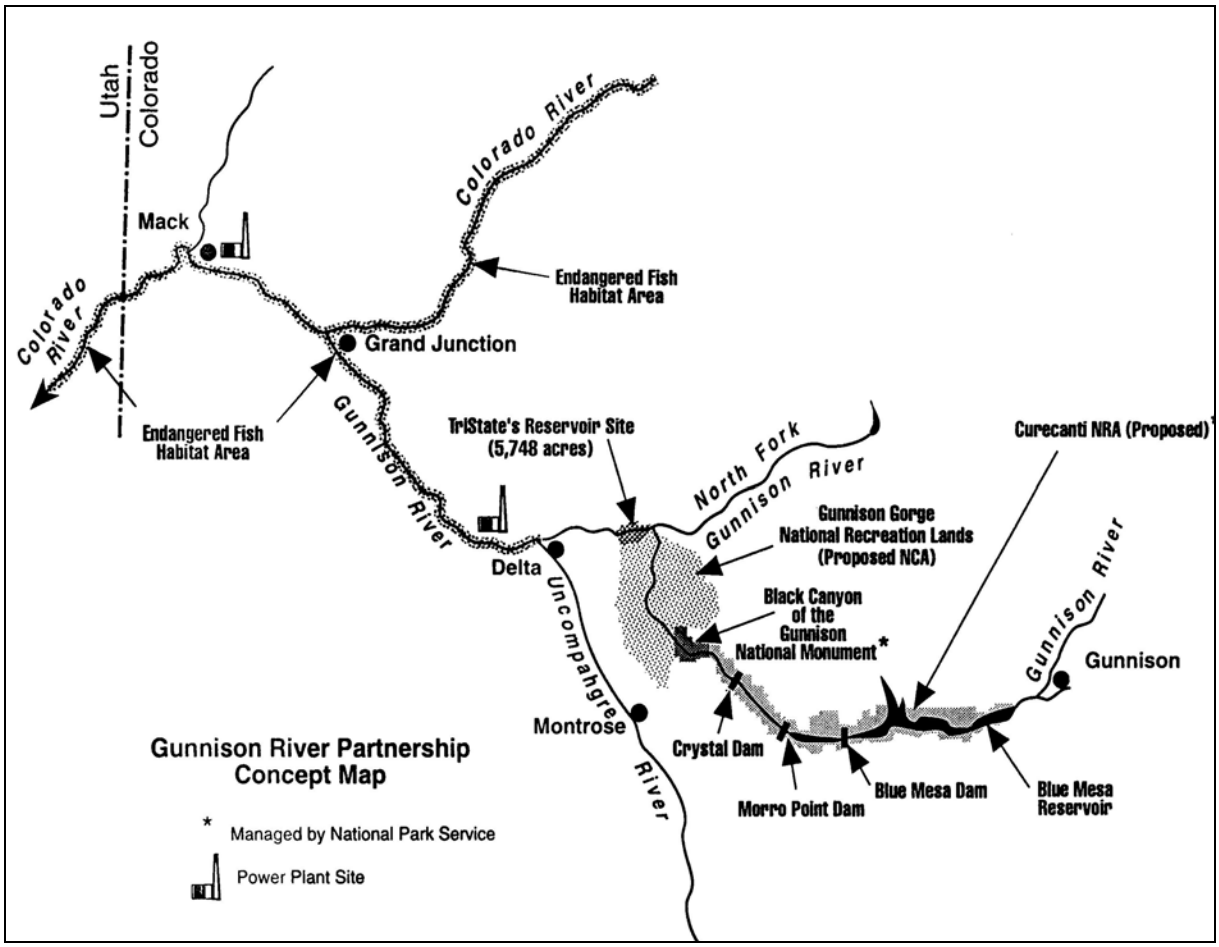

FIGURE 1 Map of the Aspinall Cascade and Surrounding Area

The Aspinall Cascade is operated as a tightly-coupled multi-purpose system. Its primary purpose is to furnish the long-term regulatory storage needed to states in the upper Colorado River Basin to meet its flow obligation at Lees Ferry, Arizona, as defined in the Colorado River Compact. Operation of the Aspinall Cascade consider power generation, projected inflows to its reservoirs, flood control needs, existing water rights, minimum instream flows, target elevations for reservoirs, flow needs for endangered fish and other resources, recreation, hydropower needs and other factors. Table 1 contains a summary of reservoir, dam, and power plant characteristics in the Aspinall Cascade.

Hydropower plant output levels in the cascade can be ramped up or down from zero production levels to maximum capability in a matter of minutes without adverse affects on the power equipment. This attribute makes it well suited to provide the interconnected grid with various ancillary services such as spinning and non-spinning reserves, regulation, and voltage support.

The Blue Mesa Dam is on the Gunnison River about 30 miles below Gunnison, Colorado. The dam is a zoned earthfill embankment with a structural height of 390 feet and a crest

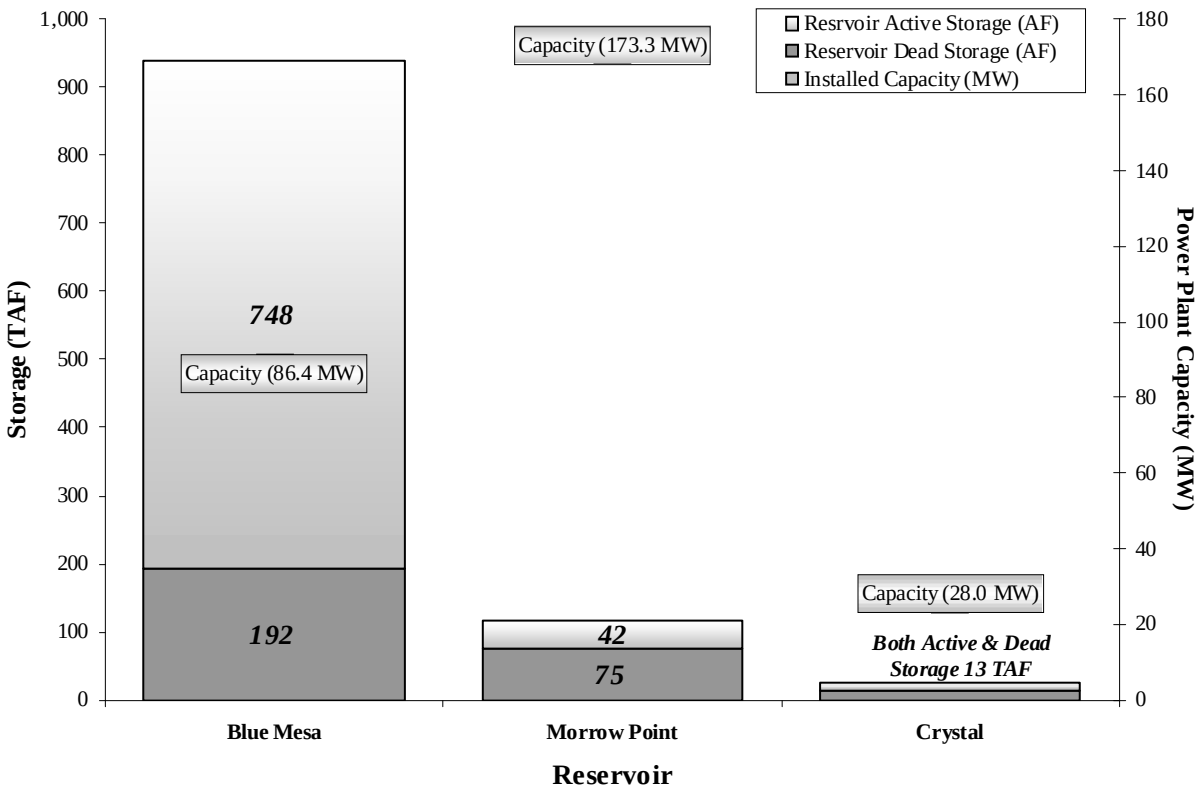

FIGURE 2 Chart of Aspinall Cascade Reservoir and Power Plant Capacities

length of 785 feet. It contains 3,093,000 cubic yards of materials. The maximum discharge of the spillway is 34,000 cubic feet per second (cfs). Blue Mesa's primary function is water storage. The reservoir has a total storage capacity of 940,800 acre-feet (AF) and an active capacity of 748,500 AF. At maximum water surface elevation, the reservoir occupies 9,180 acres.

Power generation from Blue Mesa was initially produced by a single 30 MW generator that was put into service in September 1967. Two months later, a second 30 MW unit was brought online. Both generators were uprated to 43.2 MW in 1988. The generators are driven by two 41,500-horsepower (HP) turbines. The power plant operates in a peaking mode with large hourly fluctuations in power production over the course of a day with a potential output range from zero to maximum capacity in one hour.

The Morrow Point Dam is located 12 miles downstream from the Blue Mesa Dam. It is the Bureau of Reclamation's (Reclamation) first thin-arch, double curvature dam. Constructed of 365,180 cubic yards of concrete, the dam is 468 feet high and 52 feet thick at the base, with a crest length of 724 feet. The maximum capacity of the spillway is 41,000 cfs. The reservoir capacity behind the Morrow Point Dam is 117,190 AF at maximum water surface elevation, with an active storage capacity of 42,120 AF. The surface area of the Morrow Point Reservoir is 817 acres at an elevation of 7,160 ft. The power plant produced electricity from its two 60-MW generators for the first time in 1970. The generators were uprated from 60 MW to a sustained operational level of 82.5 MW in 1992 and 1993 for a total plant capacity of 165 MW. Three single-phase transformers were replaced during water year (WY) 1996 and a 230-kilovolt (kV) cable was replaced during WY 1998.

Similar to the Blue Mesa power plant, Morrow Point is also well suited to provide the interconnected grid with various ancillary services. As shown on Table 1, these services include spinning and non-spinning reserves, regulation, voltage support, and system black start.

TABLE 1 Characteristics of Aspinall Cascade Resources

Dam, Reservoir and Power Plant Characteristics	Blue Mesa	Morrow Point	Crystal
Dam Type	Earthfill Embankment	Double-Curvature Thin-Arch	Double-Curvature Thin-Arch
Primary Purpose	Water Storage	Power Production	Flow Regulation
Dam Height (ft)	502.0	468.0	323.0
Spillway Crest Elevation (ft)	7,487.9	7,123.0	6,756.0
Crest Elevation (ft)	7,528.0	7,165.0	6,772.0
Active Reservoir Capacity (AF)	748,500	42,120	13,000
Surface Area (acres)	9,180	817	340
Power Plant In Service Year	1967	1970	1978
Total Installed Capacity (MW)	86.4	173.334	32.0
Number of Turbines	2	2	1
Typical Production Mode	Peaking	Peaking	Base Load
Maximum Annual Generation 1992-2001 (GWh)	372	517	218
Minimum Annual Generation 1992-2001 (GWh)	205	271	151
Spinning Reserve	Yes	Yes	Yes[1]
Non-Spinning Reserve	Yes	Yes	Yes[1]
Replacement Reserve	Yes	Yes	Yes[1]
Regulation/Load Following	Yes	Yes	Yes[1]
Black Start	Yes	Yes	Yes[1]
Voltage Support	Yes	Yes	Yes[1]

[1] The Crystal power plant is physically capable of providing these ancillary services but institutional and environmental constraints preclude Crystal from operating in a mode such that these services can be sold on the market

The Crystal Dam is located 6 miles downstream from the Morrow Point Dam and approximately 20 miles east of Montrose, Colorado. Its operations stabilize the flow of water through Gunnison National Park, in addition to functioning as a power generation unit. The dam is a double-curvature thin-arch type, 323 feet high, with a crest length of 635 feet. The dam contains 147,000 cubic yards of materials. The reservoir storage capacity behind the Crystal Dam is 26,000 AF at maximum water surface elevation, with an active capacity of 13,000 AF. Its surface area is 340 acres at full reservoir.

Power generation from the Crystal plant began in July 1978. The plant currently has an installed capacity of approximately 32 MW from one unit driven by a 39,000-HP hydraulic turbine. Although the Crystal power plant has the physical capability to provide all types of ancillary services (see Table 1), the flat flow requirement precludes it from rapidly changing power output from one hour to the next.

Model Process Overview

The economic evaluation of Aspinall power resources is a multi-step procedure consisting of data processing and computer simulations. Computer simulations and economic calculations are performed for each EIS alternative. A flow diagram depicting the major components of this procedure and component interactions is displayed in Figure 3. The process begins with RiverWare simulations that were performed by Reclamation and sent to both Western and Argonne National Laboratory (Argonne). RiverWare produces daily RiverWare results for each of the three hydropower plants in

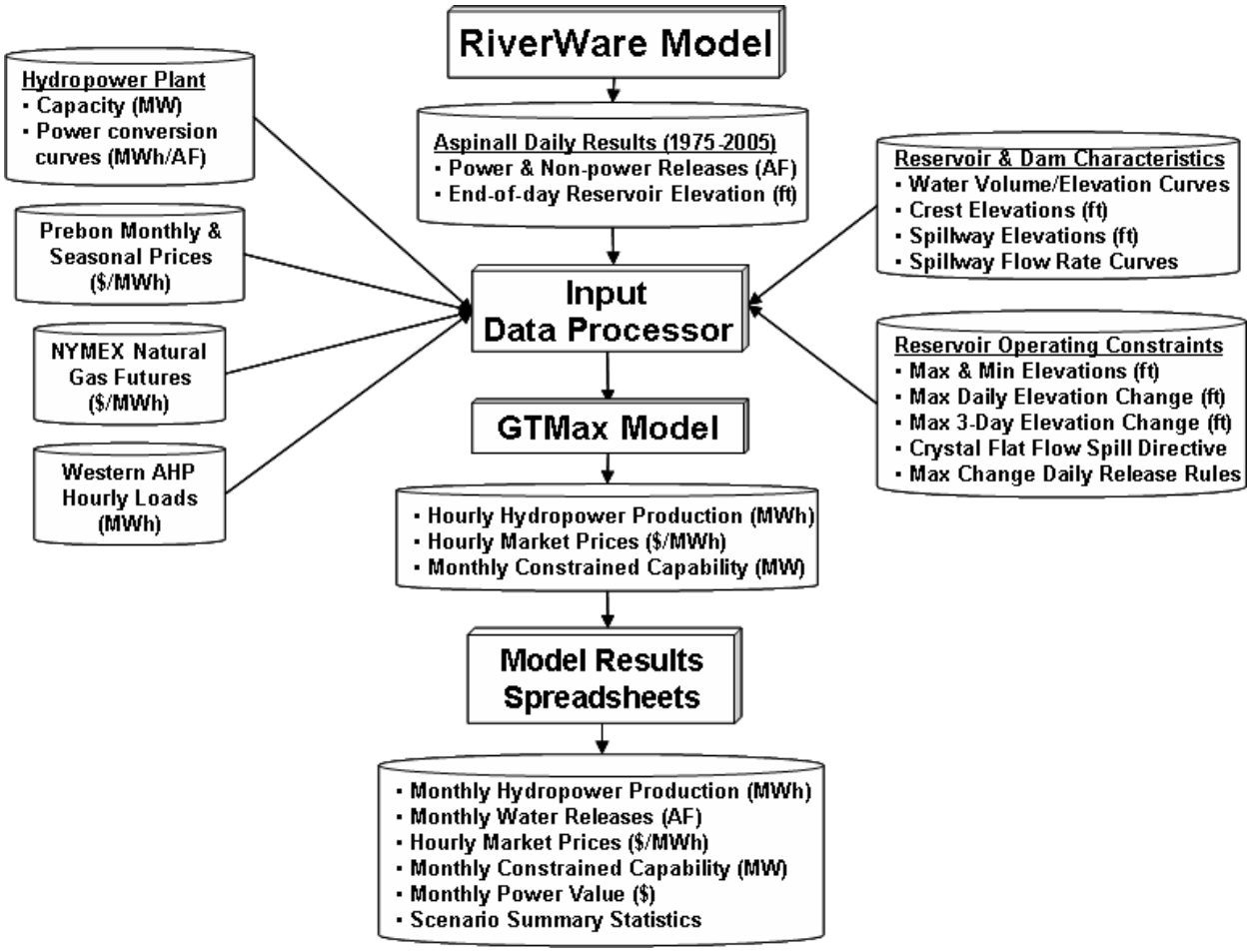

FIGURE 3 Diagram Depicting Major Modeling Components and Processes

the cascade that include Blue Mesa, Morrow Point, and Crystal. For each of the six EIS alternatives, RiverWare results used for power economics analyses include daily turbine water releases, bypass tube releases, and water that is released via spillways. RiverWare data for reservoir forebay elevations are also utilized for power economic computations.

RiverWare results along with hydropower plant information, reservoir characteristics, market prices, load profiles, and operating constraints are input into an Excel spreadsheet that prepares data for the Generation and Transmission Maximization (GTMax) model. The spreadsheet uses RiverWare reservoir elevation levels to estimate average weekly power conversion factors expressed in terms of electricity production in units of Mega-Watt-hours (MWh) per acre-feet (AF) of turbine water release. It also contains selected RiverWare data required for computations of both power production and economics.

A customized version of GTMax, specifically developed for the Aspinall EIS, simulates hourly hydropower generation at the each of the three Aspinall power plants. It determines the hourly operation schedule over a one-week period (i.e., 168 hours) that maximizes the economic value of Aspinall hydropower resources. The operation schedule produced by the model is within the physical limitations of each power plant and associated reservoir. It also complies with all environmental and institutional regulations. GTMax results include an estimate of the economic value of Aspinall energy production over the simulation period. It also estimates hydropower plant maximum production capability taking into account all operational constraints in the cascaded system. These results are summarized and displayed in tables and graphs with via drop-down menus in Excel Results spreadsheets. More detailed information on major processes used for modeling the Aspinall Cascade is provided in the following sections.

RiverWare Model

The RiverWare model mimics operational decisions that are made for CRSP reservoirs at a daily time step. For the Aspinall Cascade, operational considerations such as meeting seasonal, monthly and daily reservoir water volumes are contained in the model. Since EIS alternatives have unique criteria, each simulation contains alternative-specific operating rules.

In addition to the influencing the timing of water releases for power production, EIS alternatives also affect reservoir forebay elevations and the amount of water that circumvent turbines via bypass tubes and spillways. The forebay elevation determines the hydraulic head and is the primary factor that influences the amount of energy that is produced per volume of water released through the turbines. High forebay elevations typically translate into more power production per AF of turbine water releases as compared to power production at lower forebay elevations. However, maintaining full or nearly full reservoirs increases the risk of releasing water through bypass tubes and spillways. Sudden unexpected inflows under a full reservoir condition may require reservoir releases that exceed maximum turbine flow rates, resulting in water releases without power production. On the other hand, maintaining lower reservoir levels will reduce the risk of non-turbine water releases during flood conditions, but it will also

result in lower power conversion factors and increase the risk of lowering the forebay elevation below turbine inlet tubes during droughts. When this occurs, both power production and the plant capacity are zero. Operating rules must balance the risks associated with either having too much or not enough water stored in Aspinall reservoirs.

Balancing risks in a basin with large variations of water inflows, such as the Aspinall Cascade, require a full-spectrum examination of hydrological conditions. Therefore, the RiverWare model was run for a sequence of historical inflows that occurred from the beginning of 1975 through the end of 2005. RiverWare results include scenario-specific estimates of daily water releases and reservoir elevations throughout the analysis period.

Monthly release patterns affect the economic value of the hydropower resource since electricity prices are highly sensitive to seasonal and hourly variations in market forces. Typically market prices are the highest in the summer and winter seasons. Therefore, from a myopic power viewpoint that only considers the Aspinall Cascade, water releases would ideally be concentrated during these two seasons. However, from a broader perspective, power benefits must be weighted against other operational objectives, such as flood control, irrigation, municipal and industrial water supplies, recreation, and the environment.

Input Data Processor

The Input Data Processor spreadsheet translates RiverWare results into a form that can be utilized by the GTMax model. It also contains other vital information that is transferred to and utilized by GTMax. For example, the spreadsheet aggregates daily water releases into weekly total amounts and it computes average weekly power conversion factors based on RiverWare reservoir elevation levels.

For each GTMax simulation, the Input Data Processor prepares data for the following three time periods: previous events including initial conditions, a principal simulation week, and a one week extension period. The previous time period can be either actual historical events or events that were simulated by GTMax in a prior run. The Aspinall EIS utilizes simulated results for a prior modeled time period. For example, when modeling the second week in January, the Input Data Processor retrieves GTMax results for the first week in January.

The spreadsheet prepares data for a two week time period, since for each GTMax run 14 days of operations are simulated. The first seven days are referred to as the principal time period and the second seven days is the one week extension period. Although results for only the principal time period is used in the economic analysis, the extension period is important since it significantly reduces modeling boundary problems associated with end-effects. If the simulation were only run for seven days, model results would be valid, but results for the end states (i.e., last simulation hours) may be in a position that is detrimental for operating efficiently in the following week. By running 14 days instead of just seven, the model recognizes that operations in the principal time period have consequences on following week perations. Data that are prepared by the spreadsheet for both weeks include hourly inflows into the Blue Mesa reservoir, hourly side flows for

Morrow Point and Crystal, power conversion factors and weekly water releases from each reservoir. Operational constraints for both the reservoir and power plant operations are also determined and input into GTMax by the Input Data Processor

The following example illustrates this process. When determining simulation results for the second week in January, both the first (principal period) and second week (extension period) are simulated. A simulation of the third week in January uses results from the second week model run to determine what occurred in the previous week and both the third and fourth weeks in January are simulated. Note that the third week in January is simulated twice; that is, it is first simulated as an extension period and then as the principal week in the second run. Results for the all extension periods are discarded.

Accounting for events that took place in the past is necessary since the Crystal reservoir forebay elevation cannot fluctuate by more than a specified level in any three day period. Therefore, when simulating the future during the principal simulation period, Crystal reservoir conditions that occurred during the past three days restrict reservoir operations in the future. There is also a similar restriction that limits Crystal operations over a one day period. The Input Data Processor spreadsheet computes daily maximum and minimum historical Crystal reservoir elevations and passes this information to GTMax. The spreadsheet also determines initial conditions for all three reservoirs. Initial conditions serve as a starting point for computing future elevations.

GTMax hourly simulation of the Aspinall Cascade must consider numerous limitations as summarized in Table 3. The spreadsheet determines limitations placed on Morrow Point and Crystal that vary by period. Limits on the changes in Crystal's reservoir elevation over time help maintain the reservoir storage quality. When soil on the reservoir shoreline is saturated in the springtime, it becomes unstable and rapid water elevation changes may result in landslides.

TABLE 3 Short-term Operational Restrictions for Aspinall Reservoirs

Blue Mesa	**Jan - Mar**	**Apr - Dec**
Minimum Elevation (ft.)	7,393.0	7,393.0
Maximum Elevation (ft.)	7,490.0	7,519.4

Morrow Point	**Jun – Sep**	**Oct - May**
Minimum Elevation (ft.)	7,151.0	7,143.0
Maximum Elevation (ft.)	7,160.0	7,160.0

Crystal	**Apr – Jun**	**Jul - Mar**
Maximum Change per Day (ft.)	4	10
Maximum Change per 3 Days (ft.)	6	15
Elevation (ft.) for 1/2 ft. / Day Max Change	6,748	6,733

The Aspinall reservoirs are also operated to meet the delivery requirements of the Uncompahgre Valley Project and to keep a minimum of 300 cfs of water flowing through the Black Canyon of the Gunnison National Park. Operations must also maintain a minimum summertime flow of 300 cfs below the Redlands Diversion Dam. It is located on the Gunnison River, 2.3 miles upstream of the confluence with the Colorado River. This requires that hourly water releases from the Crystal reservoir are nearly constant. Minor fluctuations of approximately 50 cfs occur due to limitations in the automatic control equipment at Crystal. Under very wet hydrological conditions, when spillway releases are required at Crystal, releases from Morrow Point must also be constant in order maintain constant water releases from Crystal.

The Input Data Processor also contains detailed data that describe the characteristics of the Aspinall Cascade in terms of water storage, power production and the market in which it operates. Reservoir and hydropower plant characteristics are summarized in Table 1.

Figures 4 through 6 contain graphs of Aspinall reservoir elevations as a function of water volume. These functions are all non-linear and are described by fourth-order polynomial equations contained in the spreadsheet. Coefficients of polynomial equations that describe curve shapes are provided in Table 4.

TABLE 4 Polynomial Coefficients for the Reservoir Elevation Function

Reservoir	Intercept	Slope	2nd Order	3rd Order	4th Order
Blue Mesa	7.37E+03	3.49E-04	-4.13E-10	3.53E-16	-1.24E-22
Morrow Point	7.02E+03	1.17E-03	3.09E-10	0.0	0.0
Crystal	6.67E+03	7.13E-03	-1.65E-07	2.14E-12	0.0

The GTMax model uses Linear Programming (LP) techniques to maximize the value of Aspinall resources. Therefore, the non-linear reservoir representation described by the polynomial equations cannot be directly entered into the model. Therefore, the Input Data Processor approximates the elevation and water storage relationship for an Aspinall reservoir into a single linear function, written in slope-intercept form. While the linear equation does not capture the exact relationship, it is an accurate approximation when the linear function is used to represent a small segment of the non-linear curve.

The Input Data Processor determines the segment of the curve that will be applicable for each simulated week by examining daily reservoir elevations provided by RiverWare. The slope of the relationship is based on a straight line that connects the minimum and maximum elevation levels that are expected to occur within each simulated weekly period. Elevation inaccuracies associated with this technique are almost always less than two-tenths of an inch for the Blue Mesa Reservoir. Errors for the Morrow Point and Crystal Reservoirs are somewhat larger, but almost always less than an inch. For the purposes of this analysis, the linear reservoir representation is a reasonably accurate

representation considering potentially large errors in other model variables such as seasonal and hourly market price profiles.

The Input Data Processor generates hourly market prices for the GTMax model based on prices that were current at the time when the study was initially conducted in the summer of 2007. Average seasonal on-peak and off-peak prices were obtained from Prebon which, along with NYMEX natural gas futures, were used to estimated the monthly prices shown in Table 5.

Using hourly customer loads for a typical Saturday, Sunday, and weekday as a guide, estimates of hourly market prices were approximated using a pricing heuristic that is part of the Input Data Processor. The heuristic uses monthly derived on-peak and off-peak prices to produce a set of 168 values for each simulated week. Prices produced by the routine have a shape that is similar to the load patterns. However, based on observations that the supply curve is typically steeper at higher load levels as compared to prices at lower loads, market prices during high load periods are typically more expensive than prices during off-peak times. The final result of the procedures shown in Figure 7 is a set of hourly prices that have an average value that is nearly identical to the monthly on and off-peak prices shown in Table 5. The pricing procedure used in this analysis is identical to the one that Western uses each month forecast future purchase requirements.

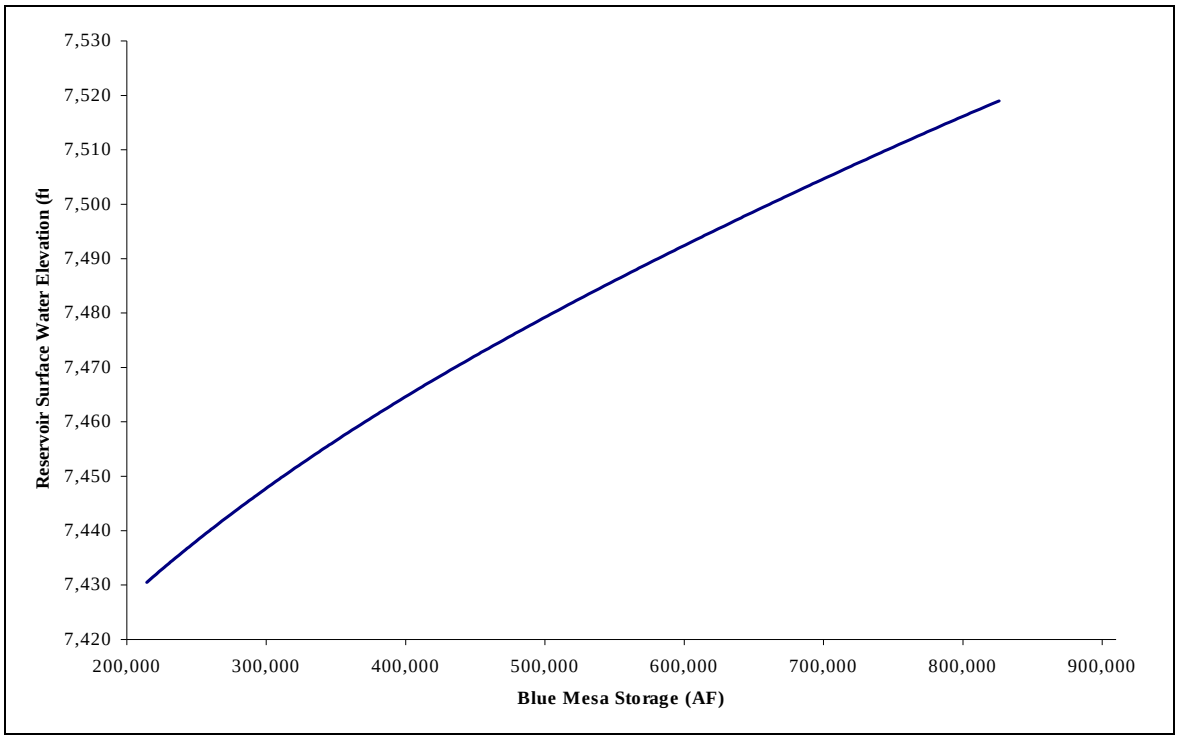

FIGURE 4 Blue Mesa Reservoir Elevation as a Function of Water Storage

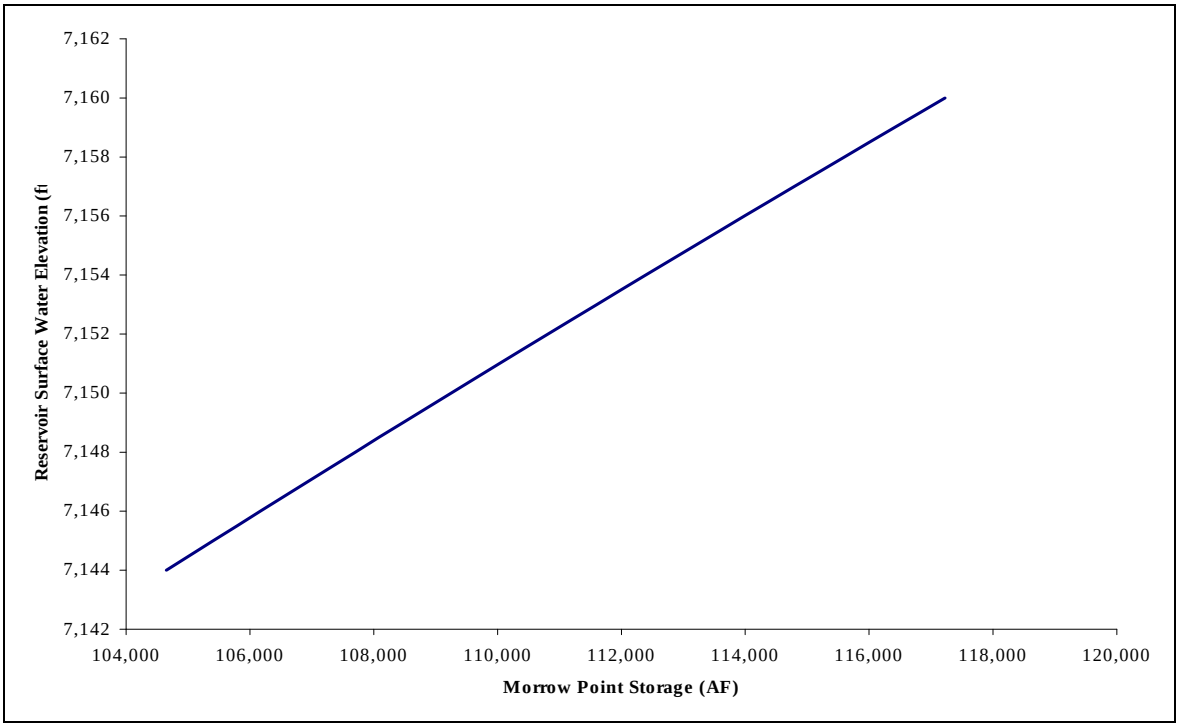

FIGURE 5 Morrow Point Reservoir Elevation as a Function of Water Storage

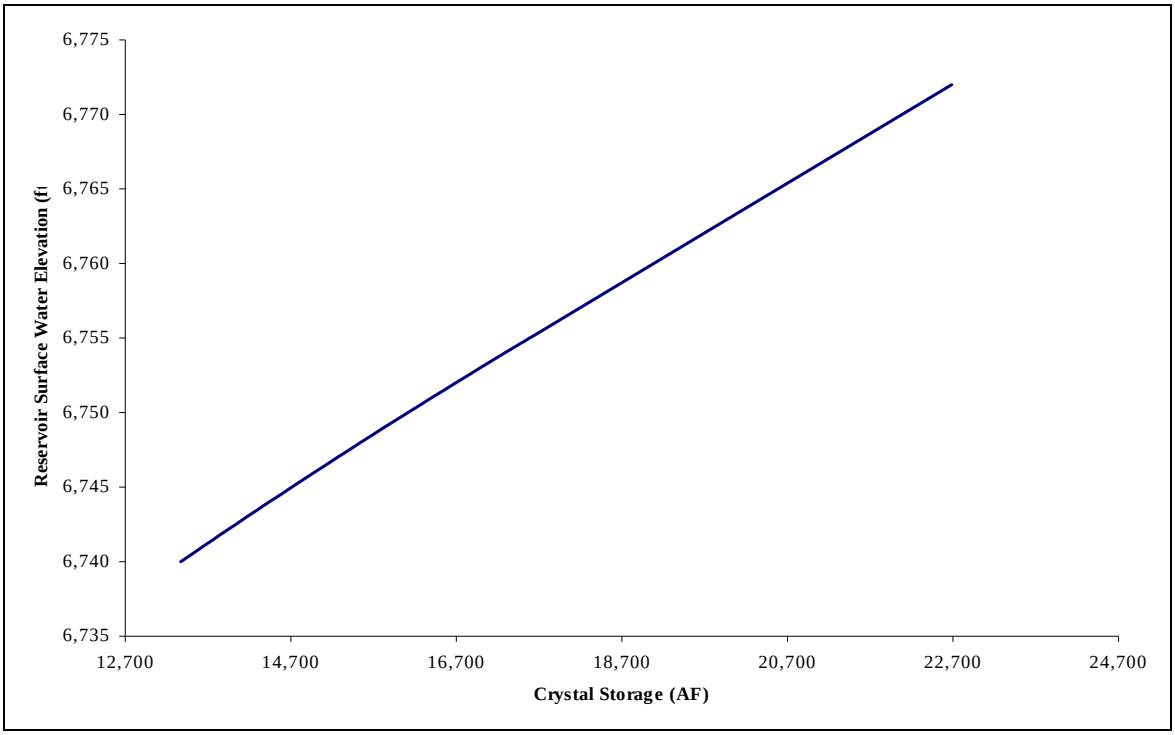

FIGURE 6 Crystal Reservoir Elevation as a Function of Water Storage Volume

TABLE 5 Short-term Operational Restrictions for Aspinall Reservoirs

Quarter	Month	Prebon Price ($/MWh)		Nymex Nat. Gas Futures ($/MMBtu)	GTMax Average Monthly Price ($/MWh)	
		On-Peak	Off-Peak		On-Peak	Off-Peak
NA	June	$ 75.50	$ 54.10	7.682	$ 75.50	$ 54.10
Q3 07	July	$ 91.25	$ 65.39	7.823	$ 91.25	$ 65.39
	August	$ 93.13	$ 66.73	7.915	$ 93.13	$ 66.73
	September	$ 73.62	$ 52.75	8.059	$ 73.62	$ 52.75
Q4 07	October	$ 69.00	$ 49.44	8.804	$ 69.00	$ 49.44
	November	$ 69.00	$ 49.44	9.534	$ 74.72	$ 53.54
	December	$ 69.00	$ 49.44	9.889	$ 77.50	$ 55.54
Q1 08	January	$ 75.75	$ 54.28	9.887	$ 75.75	$ 54.28
	February	$ 75.75	$ 54.28	9.662	$ 74.03	$ 53.04
	March	$ 75.75	$ 54.28	8.652	$ 66.29	$ 47.50
Q2 08	April	$ 72.75	$ 52.13	8.407	$ 72.75	$ 52.13
	May	$ 72.75	$ 52.13	8.317	$ 71.97	$ 51.57
	June	$ 72.75	$ 52.13	8.404	NA	NA

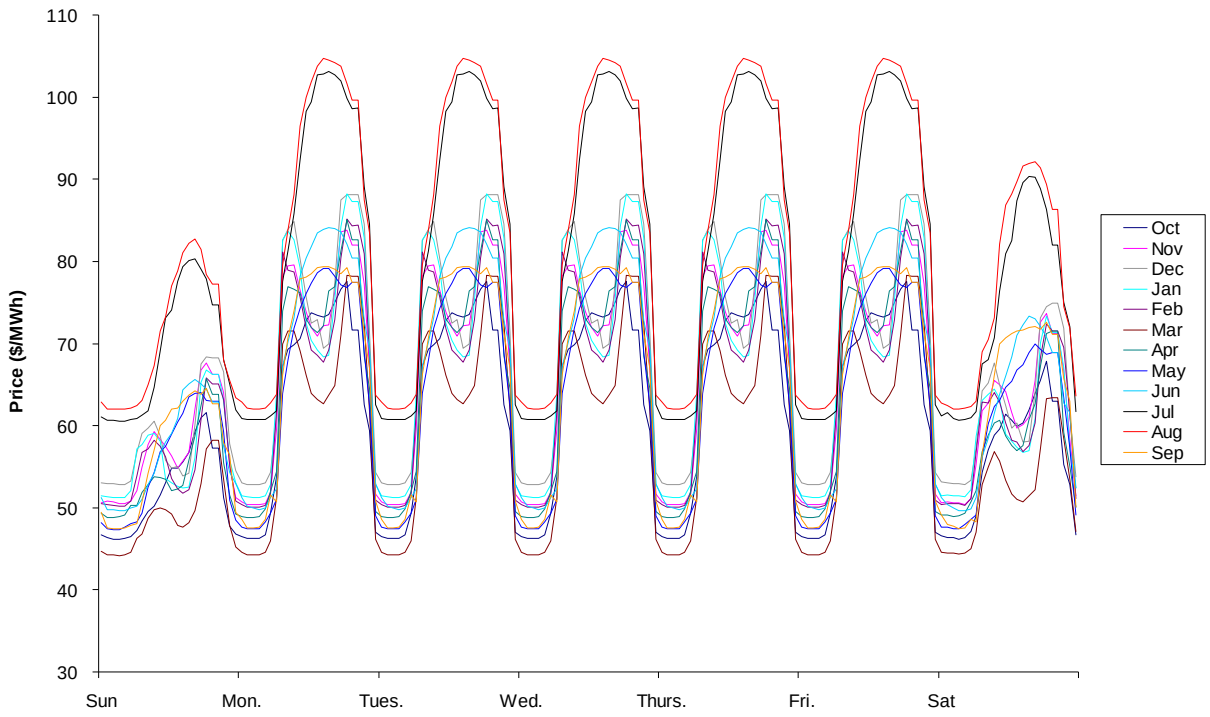

FIGURE 7 Hourly Market Prices for 12 Typical Weeks in the Year

Economic Value

The economic value or benefit of hydropower production for the modeling frameworks is based on the operation of Aspinall power plants in the context of a large interconnected power system. In GTMax, the value of a power resource is set equal to the market price of electricity illustrated in Figure 7 multiplied by the amount of energy produced by the power plant. It is assumed that market prices reflect the marginal cost of producing electricity. Therefore the economic calculations measure the costs of the additional resources that would be needed by the interconnected system to replace the services provided by the power plants in the Aspinall Cascade. In this context, the value of Aspinall hydroelectricity equals the hourly generation from Aspinall power plants times the hourly marginal system cost of power replacement. This marginal system cost serves as a general measurement of the willingness to pay for the project's output.

The main short-run economic benefit of a hydropower resource is that it serves loads that would otherwise be satisfied by running thermal generator that have much higher marginal production costs. Therefore, the economic value of hydropower production is typically measured in terms of the system-wide production cost savings from displacing thermal power production. When hydropower plants displace expensive thermal generation, its economic value is relatively high. A lower value of hydropower is placed on generation that displaces relatively inexpensive thermal generation. The cost of energy replacement for replacing generation from power plants in the Aspinall Cascade is a

function of the demand for electricity and the slate of generating resource that can satisfy this demand.

Given limited water resource, one simple strategy for maximizing the economic value of hydropower resources involves using the limited weekly water allocation to produce and sell electricity when market prices are the highest. Electricity up to its maximum generation capability is first sold during the peak priced hours. If additional water is available for generation, power releases are scheduled during the next highest priced hours. This process continues until the allocated amount of water that can be released over a period has been exhausted. However, technical, institutional, and environmental considerations may make this simple "sell high" strategy infeasible. The constant flow requirement at Crystal along with limitations on the operation of reservoirs in the cascades places constraints on the timing of water releases and therefore power production. In general, the more control (i.e., less physical and institutional restrictions) that operators and power marketers have over the timing of water releases to follow the "sell high" model the greater the value of the resource.

The modeling frameworks presented in this report assume that the market price of energy accurately reflects the marginal value of energy. Power producers sell power into the market at the system marginal production cost and do not attempt to "game" the market. It is also assumed that power production from the cascade does not significantly affect market prices. That is the system lambda is the same with or without Aspinall power generation. Given that the Aspinall Cascade is a very small supplier in the Western interconnect, it influence on price under all but the most extreme situations (e.g., supply shortage) is negligible.

GTMax Model

Argonne simulated the operation of hydropower plants in the Aspinall Cascade on an hourly time step with the GTMax modeling software. The GTMax objective function is to produce the hourly generation schedule that maximizes the economic value of the hydropower resources. The model determines how much water to release in each hour of the simulation period and how much electricity to generate from each power plant. A driving force in modeling the Aspinall Cascade is to support decision makers through simulating cascade operations under a number of diverse rules, hydrological conditions, and power market conditions.

Market prices input into the model convey the economic value of hydropower generation. These prices heavily influence the hourly generation schedule produced by the model when optimizing hydropower plant resources. To the extent possible, the GTMax model uses limited energy resources to first generate electricity during on-peak hours when it has the highest economic value. Any remaining energy is scheduled during lower-priced hours. Aspinall power plant operations are subject to a set of constraints. These include a physical operating capability and a limit on the total weekly electricity production. These constraints are consistent with RiverWare model results. In addition to physical operating constraints, the GTMax model also complies with reservoir operating restrictions.

Figure 8 contains a depiction of a reservoir, dam, and hydropower plant along with major variables that govern the physical processes of the system. In the modeling frameworks described below, there are two types of variables. These include variables that are solved through the modeling process (black filled circles) and others that are given or assumed to occur (white filled circles).

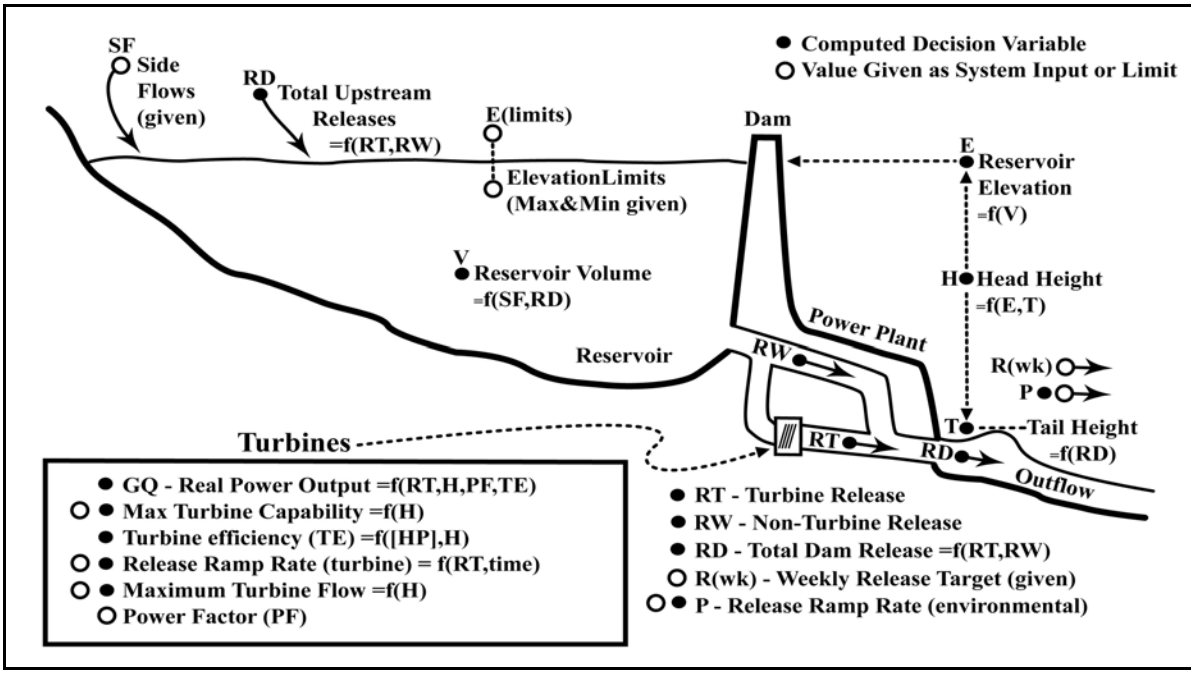

FIGURE 8 Variables and Functions for a Single Hydropower Plant

The dam regulates water inflows from upstream sources and stores water in a reservoir. Total inflows into a reservoir consist of water released from upstream reservoirs *RD* and from side flows *SF*. A side flow is a source of water that enters the stream in-between two reservoirs or a water source that feeds directly into the downstream reservoir. It can also represent water that is extracted from a reservoir. For example, a negative *SF* value indicates that water is taken out from either the stream or reservoir through seepage, by evaporation, or for uses such as irrigation. Side flows are input (i.e., a given variable based on RiverWare results) into the model. Water is released from the reservoir (referred to as outflows) through the penstock and past turbine blades *RT* to produce power or through bypass tubes and spillways in which no power is produced *RW*. Both the timing and routing of water releases (i.e., power and non-power releases) are solved by the model and are the most critical variables for optimizing the economic value of hydropower resource. Values for *RT*, *RW*, *RD*, and *SF* are expressed in terms of total water release in AF from the end of hour h-1 to the end of hour h. It is assumed that the instantaneous flow rates over the simulated hour are constant.

The volume of water stored in a reservoir V at any simulated hour h is computed by the model as a linear water balance equation. Variables included in the mass balance equation are the initial reservoir volume at hour h_o (i.e., given state of the reservoir before

the first simulation hour), reservoir inflows from hour *h*-1 to hour *h*, and reservoir outflows from hour *h*-1 to hour *h*. The time-step used for modeling the Aspinall Cascade is one hour and computed values for the reservoir volume are at the end of each hour.

The elevation of the water surface in the reservoir *E*, is a function of the amount of water that it stores. The model computes the forebay elevation based on the reservoir volume. At a low reservoir elevation a small change in water storage results in a relatively large elevation change and when the reservoir is full a small decrease in reservoir water storage results in a relatively small change in reservoir elevation. The reservoir elevation level is typically constrained such that it remains within a given range (referred to as *E*(limits) in Figure 8). Since the reservoir volume *V* is at the end of hour *h*, the computed reservoir elevation at the end of each hour.

The Crystal reservoir is constrained by the rate of reservoir elevation change over time. As shown on Table 3, the Crystal reservoir has limits on both daily and three day reservoir elevation changes. Both reservoir elevation limits and the rate of elevation change are operating rules that are established to maintain the reservoir storage quality. Computations of the reservoir water levels are not only important for ensuring compliance with reservoir operating rules, but are also key factors that determine power output from hydropower plants.

The relationships among the physical components of the Aspinall Cascade in terms of key modeling variable are shown in Figure 9. It illustrates that any action, usually in the form of a water release, at a reservoir will not only affect the current and future output level of its power plant, but it will also impact the operation of other cascade components over time. For example, when an AF of water is released from Blue Mesa in hour *h*, Blue Mesa's reservoir will be slightly lower thereby affecting power production throughout the remainder of the simulated period. On the other hand, the Blue Mesa release will increase the reservoir elevation at Morrow Point and impact its power production over time. Therefore, maximizing the economic value of a tightly coupled cascade requires that the optimization be preformed across both time and space.

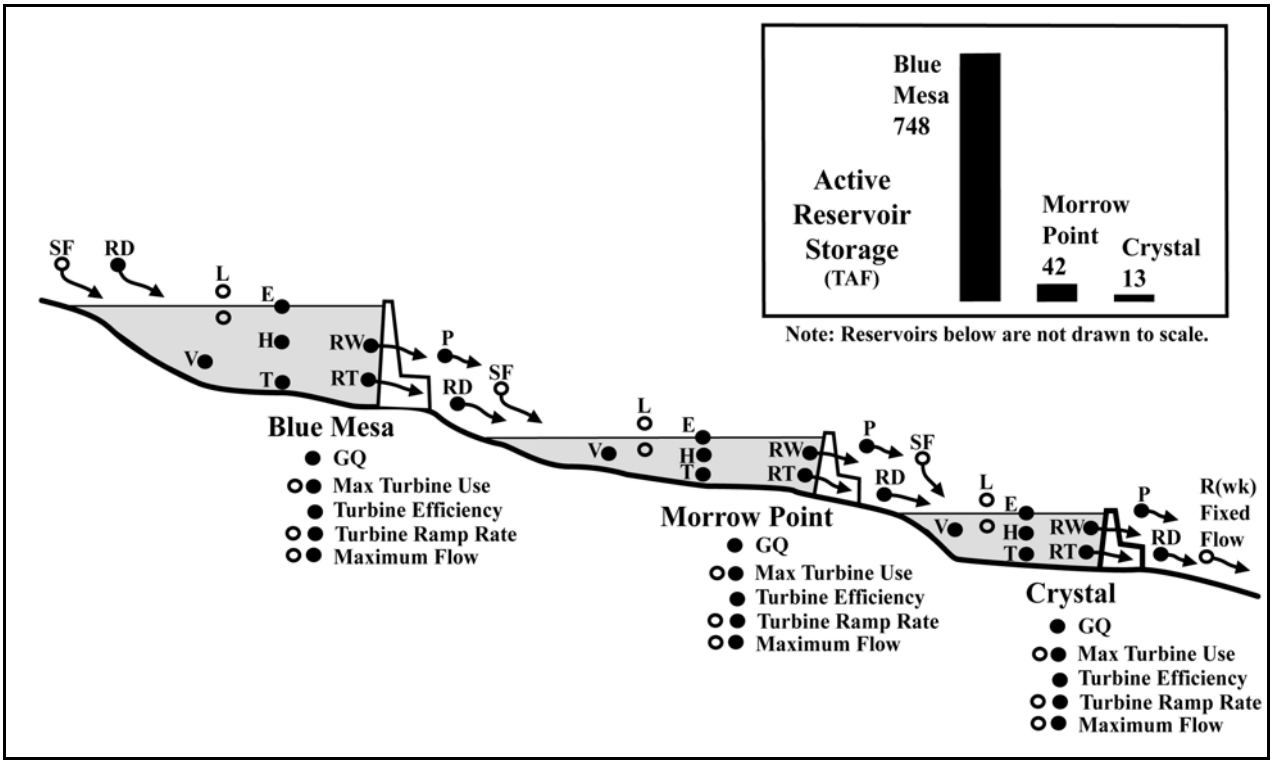

FIGURE 9 Aspinall Cascade Interdependencies

GTMax Mathematical Formulation

The GTMax model describes the Aspinall Cascade and its operations as a set of mathematical equations. These equations, provided in Table 6, consist of an objective function that is subject to a set of constraints. Equation 1, the objective function, is to maximize the value of Aspinall hydropower resources. It is set equal to the market price of electricity times the generation from all cascade power plants located at dams *d* and over all hours *h* during a two week simulation period. Although not shown in Equation 1, the objective function also contains other terms that give some actions preference over others. For example, water releases through hydropower plant turbines has a higher priority than releasing water through non-power outlets such as bypass tubes and spillways. The index *d* in the objective function equation represents cascade dams where 1 is used for Blue Mesa, 2 is for Morrow Point, and 3 is for Crystal. The hour index *h* spans 336 hours in the simulation period.

The maximization objective is subject to a set of constraints that restrict the operation of power plants and reservoirs in the cascade by the following means:

(1) limits the total water release volume from each reservoir during each simulated week;

(2) maintains a “conservation of mass” or “mass water balance” in tracking the water as it flows into and through the cascade;

(3) limits reservoir elevation levels and changes in forebay elevation levels over time and thus, operational water volumes in the reservoirs;

(4) limits hourly changes in reservoir water releases;

(5) constrains water releases through hydropower turbines; and,

(6) relates attributes such as reservoir forebay elevations to water volumes and turbine generating performance.

Optimizing Aspinall Cascade operations is a complex problem involving a combination of reservoir operations and scheduling power production. Modeling the system is further complicated by the myriad of potential reservoir operating rules that may be adopted. The challenge lies in the fact that each reservoir in the cascade can have a very large number of potential states at any one point in time. Aspinall reservoir states can become prohibitively large as the number of feasible states that must be examined grows rapidly as the simulation period increases and as the system becomes more complex. Cascade components are also highly interdependent such that operations at one reservoir have an effect on the other reservoirs in the system.

The LP formulation used by GTMax is well suited for efficiently solving the series of mathematical equations that describe the Aspinall system since all variables are simultaneously solved throughout the cascade over time. The problem formulation is "linear" since the objective function and all of the constraints are stated as strict continuous linear equations. Given the mathematical statement of the problem, the LP solution is guaranteed to be optimal.

In reality, many of the relationships in the cascade are *not* strictly linear. Therefore, a non-linear statement is approximated with one or more bounded linear equations. Non-linear functions include computations of reservoir water forebay elevations and power conversion factors.

The continuity constraint shown in Equation 2 maintains that total hourly water releases over all days *day* from each dam *d*, in a week will exactly equal the given weekly release target for the dam. Based on RiverWare model results, weekly target release volumes for GTMax are computed by the Input Data Processor spreadsheet such that the two models release the same amount of water each week. Separate values are computed and applied to the principal simulation period (wk=1, h=1 through 168) and extension weekly period (wk=2, h=169 through 336).

The total water release from dam *d* during day *day* is the sum of all hourly *h* releases beginning at midnight through the end of the day. It includes both turbine releases and spilled energy (non-turbine) releases at a dam in Equation 3. Hourly non-turbine water releases include releases through both the bypass tubes and spillways as described in Equation 4. It should be noted that GTMax daily water releases are not restricted and may

therefore differ from daily values generated by the RiverWare model. However, as stated by Equation 3, both models have identical weekly water releases.

The maximum hourly water flows through turbines at a power plant for electricity production is limited by the generating capacity of the turbines at a dam and the power conversion factor as described by Equation 5. Maximum turbine flow rates are computed separately for the principal simulation period and the extension period. Hourly releases above the maximum power plant level are released through the bypass tubes and spillways. The GTMax model is formulated such that non-power water is first released through bypass tubes up to a maximum level described by Equation 6. Releases via spillways are used as a last resort.

The power conversion factor is a function of the forebay elevation level using a second order polynomial equation (Equation 7). Coefficients that describe the shape the power conversion curve for each hydropower plant in the Aspinall Cascade were jointly derived by Western and Reclamation (see Table 7). The coefficients are based on monthly historical values of end-of-month (EOM) reservoir elevations, monthly power production levels, and monthly turbine water releases as documented in PO&M-59 reports.

Estimated by Equation 8, hourly generation equals the weekly power conversion factor multiplied by turbine water releases. The average weekly reservoir elevation used in the equation is computed by the Input Data Processor spreadsheet using information from the RiverWare model. It should also be noted that the power conversion factor is held constant throughout a simulated week. In reality, reservoir elevations will fluctuate on an hourly basis, but these fluctuations tend to be small, especially at Blue Mesa and Morrow Point, having only a minimal affect on power conversion factors. These releases are constrained by Equation 5 which guarantees that power production levels do not exceed the power plant capacity. The timing of turbine water releases and hence generation is paramount to the optimization problem. Note that the hourly value of power in Equation 1 is given and therefore only hourly generation is solved for by GTMax.

Releases are restricted by numerous reservoir operating constraints. One set of restrictions limit forebay elevations and changes in elevations over time. The GTMax model first computes water storage levels in each reservoir and then estimates the reservoir elevation level. To track the water volume stored in a reservoir, Equation 9 is used to compute the volume in the first simulation hour for the Blue Mesa Reservoir (d=1). Equation 10 is used for all other simulated hours. These two equations maintain a "conservation of mass" for water in the Blue Mesa reservoir which is positioned at the top (i.e., highest elevation) of the Aspinall Cascade. The current water volume stored in the reservoir at the end of any hour h equals the stored water at the end of the previous hour minus the water released from it in the current hour plus all inflows into the reservoir during the current hour.

The flow of water through the cascade is tracked on an hourly basis and the water mass is conserved as it flows from Blue Mesa, first to the Morrow Point (d=2), and then to the Crystal (d=3) reservoir. Water volumes in lower reservoirs are first initialized for the first

hour with Equation 11 and then computed for all subsequent hours with Equation 12. The volume of water at a lower reservoir (i.e., d>1, Morrow Point and Crystal) in the first hour equals the given initial volume at the reservoir plus releases from the reservoir immediately above it during the current hour plus the total side flows into it during the current hour minus the total release from the reservoir in the current hour. Note that a release from an upstream dam *d* in hour *h* will reach the reservoir below it (i.e., *d+1*) during the same hour *h*. This is consistent with observed swift water flow rates in the Gunnison and the close proximity of the dams in the Aspinall Cascade.

Reservoir water surface elevation must be tracked in order to ensure that the change in reservoir elevation at Crystal does not exceed set limits between midnight and midnight of each day and during rolling three day periods. Also, the reservoir elevation along with turbine capacities and power conversion factors are used to limit the maximum flow through electric turbines at all three reservoirs.

Reservoir elevation is tracked as a function of reservoir volume. The model formulation addresses the relationship between reservoir elevation and water storage volume for an Aspinall reservoir as a single linear function, written in slope-intercept form with Equation 13. The water forebay elevation at a dam's reservoir *d* during each hour *h* must remain within the preset maximum and minimum bounds given in Table 3. Equation 14 ensures that the elevations are compliant with these bounds. The elevation of each reservoir is expressed through its observed relationships with the reservoir volume. As describe in a previous section, some minor errors are introduced by linear reservoir elevation functions.

Additional constraints are needed to comply with reservoir elevation fluctuations at Crystal for each midnight-to-midnight period and for fluctuations over three day periods. Restrictions in daily fluctuations are formulated through at two-step process. First, daily minimum and maximum forebay elevation levels are computed by Equations 15 and 16, respectively. Then the difference between the maximum and minimum is computed by Equation 17. Equations 15 through 17 are extended backwards in time to restrict reservoir elevations during the first two simulated days based on reservoir elevations prior (historical or modeled) to the start of the simulated week. Note that the starting value for the day index *day* begins with -2.

Equation 18 constrains reservoir elevation fluctuations each day. Day elevation changes are limited during the entire 14 day simulation period; however, the limit may differs from one weekly period to the next. Equations 19 through 22 constrain three day reservoir elevation changes at Crystal. Operations are constrained by not only dependent on the 14 day simulation period, but also past operations as indicated by the negative day index.

Note that the daily elevation change equation is written only for the period from midnight-to-midnight. This is consistent with current regulations. However, in this form, there is no guarantee that a larger fluctuation might not occur during any 24-hour period. For example, a 24-hour period that begins at 9:00 AM and ends at 9:00 AM on the following day. However, since Crystal's release rate is flat and Morrow Point's turbine

flow rate is also limited, the degree to which the rolling 24-hour fluctuation is greater than the midnight-to-midnight fluctuation tends to be very small.

The hourly ramp rate describes the change in water release from one hour to the next as computed by Equation 23. The ramp rate is given as the difference in releases between two consecutive hours from dam *d*. A positive ramp rate indicates the generation is increasing over time and a negative value indicates that it is decreasing. Hourly ramp rate limits are constrained by Equation 24. In the current formulation, the ramp rate limit at Crystal Dam is set equal to zero in most hours; that is, water releases remain constant from hour to hour. However, between mid-night and 1 AM, Crystal release changes at are unconstrained. At all other dams the ramp rates are essentially unlimited; that is, constraints that limit temporal changes in releases are non-binding under all conditions.

In addition to limiting changes in releases from one hour to the next, GTMax also constrains changes in total daily release volumes as computed by Equation 25. The ramp rate is computed as the difference in releases between two consecutive days from dam *d*. Daily ramp rate limits are constrained by Equation 26. Under EIS restrictions the daily ramp rate only limits operations at the Crystal Dam. Under all scenarios, daily ramping is limited to increases in 500 AF per day and decreases of 400 AF per day. Changes in daily releases are also constrained on a percentage basis by Equations 27 and 28. Daily releases are restricted to an increase of 25 percent and a decrease of 15 percent. One exception is the No Action Alternative in which case the up ramp increase is limited to 15 percent.

TABLE 6 Equations for Converting ROD Operating Criteria and RiverWare Output

Description	GTMax Mathematical Formulation	
Objective Function	$Maximize\ Z = \sum_d \sum_h (GQ_{d,h} \times SP_h) \quad \forall d,\ h = 1, 2, \ldots 336$	Eq. 1
Weekly Water Release	$WR_{d,wk} = \sum_{day=(wk-1)\times 7+1}^{wk\times 7} DR_{d,day} \quad \forall\ d, wk$	Eq. 2
Daily Water Release	$DR_{d,day} = \sum_{h=(day-1)\times 24+1}^{day\times 24} RT_{d,h} + RW_{d,h} \quad \forall\ d, day$	Eq. 3
Hourly Non-Power Release	$RW_{d,h} = RB_{d,h} + RS_{d,h} \quad \forall\ d, h$	Eq. 4
Max Turbine Flow Rate	$RT_{d,h} \leq PCAP_d / CF_{d,wk} \quad \forall\ d, wk, h = (wk-1)\times 168 + 1 \ldots wk \times 168$	Eq. 5
Max Bypass Flow Rate	$RB_{d,h} \leq RB_d^{\max} \quad \forall\ d, h$	Eq. 6
Conversion Factor	$CF_{d,wk} = C_{d,0} + C_{d,1} \times E_{d,wk}^{ave} + C_{d,2} \times E_{d,wk}^{ave\ 2} \quad \forall\ d, wk$	Eq. 7
Power Plant Generation	$GQ_{d,h} = CF_{d,wk} \times RT_{d,h}^{2} \quad \forall\ d, wk, h = (wk-1)\times 168 + 1 \ldots wk \times 168$	Eq. 8

Blue Mesa 1st hr Storage	$V_{1,1} = V_{0,1} - RD_{1,1} + SF_{1,1} \quad \forall\ d=1,\ h=1$	Eq. 9
Other hr Blue Mesa Storage	$V_{1,h} = V_{1,(h-1)} - RD_{1,h} + SF_{1,h} \quad \forall\ d=1, h>1$	Eq. 10
Down Steam Reservoirs 1st hr Storage	$V_{d,1} = V_{d,0} + RD_{(d-1),1} - RD_{(d,1)} + SF_{d,1} \quad \forall\ d>1, h=1$	Eq. 11
Other hr Down Steam Reservoir Storage	$V_{d,h} = V_{d,(h-1)} + RD_{(d-1,h)} - RD_{(d,h)} + SF_{d,h} \quad \forall\ d>1, h>1$	Eq. 12
Reservoir Elevation	$E_{d,h} = \left(E_d^{Slope} \times V_{d,h}\right) + E_d^{Int} \quad \forall\ d,h$	Eq. 13
Max & Min Reservoir Elevations	$E_{d,wk}^{MIN} \le E_{d,h} \le E_{d,wk}^{MAX} \quad \forall\ d=3, wk, h$	Eq. 14
Daily Min Reservoir Elevation	$E_{d,day}^{Day\min} \le E_{d,h} \quad \forall\ d=3, day=-2...14, h=(day-1)\times 24+1...day\times 24$	Eq. 15
Daily Max Reservoir Elevation	$E_{d,day}^{Day\max} \ge E_{d,h} \quad \forall\ d=3, day=-2...14, h=(day-1)\times 24+1...day\times 24$	Eq. 16
Crystal Reservoir Elevation Daily Change	$E_{d,day}^{DayChange} = \left(E_{d,day}^{Day\max} - E_{d,day}^{Day\min}\right) \quad \forall\ d=3, day=\text{-}2...14$	Eq. 17
Crystal 1 Day Elevation Change Limit	$E_{d,wk}^{DayCMax} \ge E_{d,day}^{DayChange} \quad \forall\ d=3, wk, day=(wk-1)\times 7+1...wk\times 7$	Eq. 18
3 Day Min Reservoir Elevation	$E_{d,day3}^{3Day\min} \le E_{d,day}^{Day\min} \quad \forall\ d=3, day3=1...14, day=day3-2...day3.$	Eq. 19
3 Day Max Reservoir Elevation	$E_{d,day3}^{3Day\max} \ge E_{d,day}^{Day\max} \quad \forall\ d=3, day3=1...14, day=day3-2...day3$	Eq. 20
3 Day Crystal Reservoir Elevation	$E_{d,day}^{3DayChange} = \left(E_{d,day3}^{3Day\max} - E_{d,day3}^{3Day\min}\right) \quad \forall\ d=3, day=0...14, day3=day-2..day$	Eq. 21
Crystal 3 Day Elevation Change Limit	$E_{d,wk}^{3DayCMax} \ge E_{d,day3}^{3DayChange} \quad \forall\ d=3, wk, day3=(wk-1)\times 7+1...wk\times 7$	Eq. 22
Hourly Release Ramp Rate	$RR_{d,h} = DR_{d,h} - DR_{d,(h-1)} \quad \forall\ d=3, h=1...336$	Eq. 23
Release Ramp Rate Limits	$-RR_d^{Down\max} \le RR_{d,h} \le RR_d^{Up\max} \quad \forall\ d=3, h=1...336$	Eq. 24
Daily Release Ramp Rate	$DRR_{d,day} \le DR_{d,day} - DR_{d,day-1} \quad \forall\ d=3,\ day=1...14$	Eq. 25
Limit Daily Water Release Ramp Rates	$-DRR_d^{Down\max} \le DRR_{d,day} \le DRR_d^{Up\max} \quad \forall\ d=3,\ day=1...14$	Eq. 26
Limit % Daily Water Release Change Up	$0 \le DR_{d,day} \times DRR_d^{\%Up\max} - DRR_{d,day} \quad \forall\ d=3,\ day=1...14$	Eq. 27

Limit % Daily Water Release Change Down	$0 \leq DR_{d,day} \times DRR_d^{\%Down\max} + DRR_{d,day} \quad \forall\ d = 3,\ day = 1...14$	Eq. 28

where,

d = dam index
h = hour index
day = day index
$day3$ = three day index
wk = week index
$WR_{d,wk}$ = weekly water release (AF) from dam d during week wk
$DR_{d,day}$ = daily water release (AF) from dam d during day day
$RT_{d,h}$ = hourly turbine water release (AF) from dam d during hour h
$RW_{d,h}$ = hourly non-turbine water release (AF) from dam d during hour h
$RB_{d,h}$ = hourly bypass water release (AF) from dam d during hour h
$RS_{d,h}$ = hourly spillway water release (AF) from dam d during hour h
$PCAP_d$ = hydropower plant generating capacity (MW) located at dam d
$CF_{d,wk}$ = power conversion factor (MWh/AF) for the plant located at dam d during week wk
$RB_d^{\max}$ = hourly bypass maximum release (AF) from dam d
$C_{d,x}$ = power conversion factor polynomial coefficient x for dam d
$GQ_{d,h}$ = hourly electricity generation (MW) for the plant located at dam d during hour h
SP_h = hourly price of electricity ($/MWh) during hour h
$V_{d,h}$ = water storage volume (AF) in the reservoir located behind dam d during hour h
$SF_{d,h}$ = sideflows (AF) into the reservoir located behind dam d during hour h
$E_{d,h}$ = forebay water elevation (ft) at the reservoir located behind dam d during hour h
E_d^{Slope} = slope of the forebay elevation equation (ft/AF) for dam d
E_d^{int} = intercept of the forebay elevation equation (ft) for dam d
$E_{d,wk}^{MIN}$ = minimum allowable elevation (ft) for dam d during week wk
$E_{d,wk}^{ave}$ = estimated average elevation (ft) for dam d during week wk
$E_{d,wk}^{MAX}$ = maximum allowable elevation (ft) for dam d during week wk
$E_{d,day}^{Day\min}$ = minimum reservoir elevation (ft) at dam d during day day
$E_{d,day}^{Day\max}$ = maximum reservoir elevation (ft) at dam d during day day

$E_{d,day}^{Daychange}$	= reservoir elevation change (ft) at dam d during day day
$E_{d,wk}^{DayC\max}$	= maximum allowable daily elevation change (ft) at dam d during week wk
$E_{d,day}^{3Day\min}$	= minimum reservoir elevation (ft) at dam d during a 3 day period
$E_{d,day}^{3Day\max}$	= maximum reservoir elevation (ft) at dam d during a 3 day period
$E_{d,day}^{3Daychange}$	= reservoir elevation change (ft) at dam d during a 3 day period
$E_{d,wk}^{3DayC\max}$	= maximum allowable 3 day elevation change (ft) at dam d during week wk
$RR_{d,h}$	= hourly water release ramp rate (AF/hr) at dam d during hour h
$RR_{d}^{Down\max}$	= maximum allowable release down ramp rate (AF/hr) at dam d
$RR_{d}^{Up\max}$	= maximum allowable release up ramp rate (AF/hr) at dam d
$DRR_{d,day}$	= daily ramp rate (AF/day) at dam d
$RR_{d}^{Down\max}$	= maximum allowable daily release decrease (AF/day) at dam d
$RR_{d}^{Up\max}$	= maximum allowable daily release increase (AF/day) at dam d
$RR_{d}^{Up\max}$	= maximum allowable percent daily release increase at dam d
$RR_{d}^{\%Down\max}$	= maximum allowable percent daily release decrease at dam d
$RR_{d}^{Up\max}$	= maximum allowable percent daily release increase at dam d

TABLE 7 Polynomial Coefficients for Estimating Power Conversion Factor

Reservoir	$C_{d,0}$	$C_{d,1}$	$C_{d,2}$
Blue Mesa	323.1037	-0.087097359	5.87424E-06
Morrow Point	15,213.3109	-4.254332337	0.000297433
Crystal	2,736.1149	-0.811931703	6.02382E-05

Economic and Financial Analysis and Results

This section describes the analysis and results of the model runs completed using the methodology described above. It includes introductory pieces on generating and marketing of power from the Aspinall Units and of meeting reliability standards. It also describes the customers who contract for Aspinall electrical power through the SLCA/IP marketing.

Power Generation

Hydropower generation is directly related to the net effective head on the generating units and the quantity of water flowing through the turbines. The net effective head is the difference between the elevation of the water in the forebay behind the dam and the elevation of the water in the tailrace below the dam. The head and the quantity of water flowing through the turbines influence the maximum power output capacity of the powerplant, measured in megawatts (MW); capacity is the total powerplant generation capability at any point in time. In general, the powerplant capacity increases as a function of increasing head. However, turbine capacities or other equipment limitations may limit powerplant output levels.

Electrical power is measured in terms of capacity and energy. Electricity must be available the instant consumers need it. Capacity is important to meet consumers' instantaneous demand as they turn on lights, appliances and motors. Energy is the amount of electricity delivered over time and is measured in kilowatt-hours or megawatt-hours. One kilowatt-hour of energy delivered over one hour requires one kilowatt of capacity.

The capacity of each Aspinall Unit facility and historic average annual energy generation is summarized below:

Facility	Capacity (MW)	Average Annual Generation (MWH)
Blue Mesa	86.4	264,329
Morrow Point	165.0	343,450
Crystal	31.5	167,771

Power System Operations

Reclamation and Western work together on a daily basis in scheduling water releases and in coordinating maintenance outages. Western dispatches power generation at each facility to ensure compliance with minimum and maximum flow requirements, and comply with other constraints set by Reclamation in consultation with other Federal, State, and local entities. The CRSP Act requires that CRSP facilities, including the Aspinall Unit, "be operated in conjunction with other Federal powerplants, present and potential, so as to produce the greatest practicable amount of power and energy that can be sold at firm power and energy rates . . ." In dispatching power generation, Western must also consider its power system responsibilities associated with North American Electric Reliability Council (NERC) and Western Electricity Coordinating Council

(WECC) criteria. WECC, as a regional council of the NERC, has responsibility for coordinating and promoting electric system reliability in the provinces of Alberta and British Columbia, the northern portion of Baja California, Mexico, and all or portions of the 14 western states in between.

NERC and WECC operating criteria require Western and Reclamation to meet scheduled load changes by ramping the generators up or down beginning at 10 minutes before the hour and ending at 10 minutes after the hour. Ramping is the change in the water release from the reservoir through the turbine to meet the electrical load (or power demand). Both scheduled and unscheduled ramping are crucial in load following, ancillary services, power system regulation, emergency situations, and variations in real time (what actually happens compared to what was scheduled) operations.

Typically, power demand increases during the daylight hours as residences, commercial establishments, agriculture and industry put electricity to use. Hydropower generation can react instantaneously to the load – a pattern called load following. By comparison, coal- and nuclear-based resources have a relatively slow response time; consequently, they generally have limited load following capability in the WECC.

As a control area operator, Western regulates the transmission system within a prescribed geographic area. Western is required to react to moment-by-moment changes in electrical demand within this area, adjusting the electrical power output of hydroelectric generators within the area in response to changes in the generation and transmission system to maintain the scheduled level of generation in accordance with prescribed NERC criteria. Automatic Generation Control (AGC) is a process whereby the control system automates the water releases in a manner that follows the power system's actual dynamic demands on a moment-to-moment (typically a four-second-interval) basis.

Regulation depends on being able to ramp releases up or down quickly in response to system conditions. In addition, each utility is required to have sufficient generating capacity – in varying forms of readiness – to continue serving its customer load, even if the utility loses all or part of its own largest generating unit or largest capacity transmission line. This reserve capacity ensures electrical service reliability and an uninterrupted power supply.

Generating capacity that is connected to the power system and is in excess of the load on the system is called spinning reserve. Spinning reserves are used to quickly replace lost electrical generation resulting from a forced outage, such as the sudden loss of a major transmission line or generating unit. Additional off-line generating units are also used to replace generation shortages, but they cannot replace lost generation capacity as quickly as spinning reserves.

The two uppermost powerplants of the Aspinall Unit (Blue Mesa and Morrow Point) are critical to Western's operations in that they can be operated to provide load following to meet peak power demands. Blue Mesa and Morrow Point Powerplants operate in a peaking mode with large hourly fluctuations in power production over the course of a day

with potential ranges from zero to maximum capacity in one hour. Crystal Reservoir serves as a regulation reservoir to stabilize flows to the Gunnison River; consequently, fluctuations in power generation at Crystal are minimal. The flexibility offered by the three dams of the Aspinall Unit is very important for meeting peaking, automation generation control, and reserve sharing obligations of CRSP.

Power Marketing

Interconnecting transmission lines, both public and private, carry the power from generating facilities to major metropolitan areas and rural areas throughout the West. Western's power marketing responsibility, in most cases, begins at the switchyard of Federal hydroelectric power facilities and includes Federal transmission systems, while the hydroelectric plants are operated by Reclamation. Any power surplus or deficit affects all CRSP power customers since the CRSP marketing area is within the WECC region, which is one large interconnected system.

Western markets CRSP power and administers the power contracts for power generated from Reclamation-owned and operated hydropower facilities in the Upper Colorado Region except for a small amount of power used on Reclamation projects. Marketing of electricity is based on capacity and energy. Energy and capacity are important to meeting consumers' continuing need for electricity. With the delivery of electricity, capacity and energy are both present; however, they can be marketed and billed separately. Western's power rates usually include individual charges for capacity and energy. Currently, a CRSP power customer pays $4.43 per kilowatt –month for electrical capacity. This capacity fee is paid every month regardless of the electricity a customer actually buys. It is a fee to reserve an amount of capacity that can be called upon by the customers to generate the electricity the customer may call upon during the month. Additionally, a CRSP power customer pays 10.43 mills per kWh for electrical energy delivered. Overall, while not an additional charge to the customer, the "combined rate" for energy and capacity is 25.28 mills per kilowatt hour.

Power is marketed in terms of firm and non-firm power. Firm power is capacity and energy that is guaranteed to be available to the contractor, in accordance with the terms of the contract. A sufficient portion of the generation capacity is held in reserve to enable continued delivery of firm power even if an outage occurs at a powerplant. The amount of power that is held in reserve is established by various power pooling agreements and reliability criteria. The majority of CRSP power is sold under long-term firm power contractual arrangements.

Non-firm power is capacity and energy that is not guaranteed to be available to the contractor. Non-firm power is sold to wholesale customers that would rather purchase non-firm energy that is less expensive than the cost of their own generation or cost of alternative sources of supply. Non-firm energy is usually sold with the requirement that the sale can be stopped on short notice and the buyer must have the resource available to meet its own load. Rates for non-firm energy only include a charge for the energy delivered, since the customer has the capacity to meet its loads, if necessary. Western does not sell non-firm power on a long-term basis. CRSP power in excess of that needed

to meet long-term contractual requirements can be sold on a short term basis to wholesale customers as either firm or non-firm power.

Western allocates long-term firm capacity and energy from the various Federal powerplants, including the Aspinall Unit powerplants, in the Western States. The Salt Lake City Area Integrated Projects (SLCA/IP) is a group of Reclamation hydroelectric facilities marketed by Western which includes CRSP power and power from the Rio Grande Project and the Collbran Project. Electric capacity and energy from these hydropower plants, along with power purchased by Western, is provided to Western's power customers under contracts. Most such agreements are long-term firm contracts that specify the amounts of capacity and energy that Western agrees to deliver to its customers. Currently, the twenty year contracts for SLCA/IP power expire in 2024.

SLCA/IP Customers

Western markets SLCA/IP power, through its CRSP – Management Center Office in Salt Lake City, that serves approximately 5.8 million retail customers in rural areas and small towns in Wyoming, Utah, Nevada, Arizona, New Mexico, Colorado and Nebraska. Figure 1 shows areas served by CRSP. CRSP power customers purchasing wholesale electricity from Western are: 1) small and medium-sized towns that operate publicly owned electrical systems, 2) irrigation cooperatives and water conservation districts, 3) rural electrical associations or generation and transmission co-operatives who are wholesalers to these associations, 4) federal facilities such as Air Force bases, 5) universities and other state agencies and 6) Indian tribes. The reliance on CRSP power varies considerably among customers, with some customers receiving virtually all of their electrical service from the CRSP, to utilities in which CRSP resource is a small percentage of their total needs

Figure 10 shows the service areas for the SLCA/IP customers. Included are those areas with rural service areas as well as the service area of towns and municipalities (shown as red dots). Note that a significant portion of the Rocky Mountain states and states of the Desert Southwest receive some electrical power from the SLCA/IP power resources – including the Aspinall Units.

For the most part, the electrical power generated at the Aspinall Units, marketed by Western as part of the SLCA/IP electrical resource, serve rural areas of middle Western states. Western has estimated that 5.8 million retail customers that receive some portion of their electrical power from the SLCA/IP electrical facilities which include the Aspinall Units.

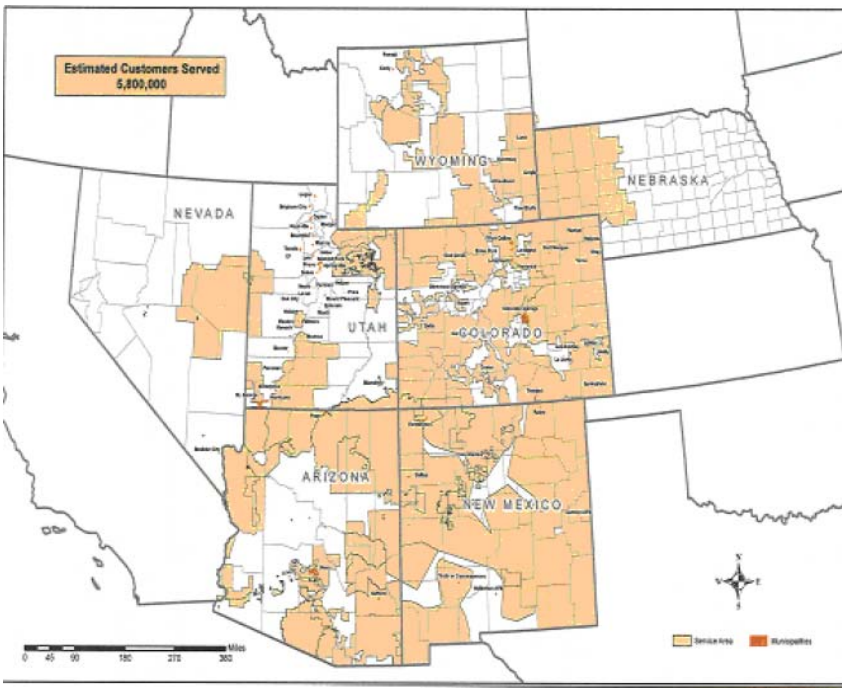

Figure 10 Service Areas of SLCA/IP customers.

SLCA/IP customers are allowed under the terms of their contracts, to schedule electrical energy to respond to changes in electrical use within their service territories. Western specifies the maximum amount of electrical energy that can be used by a customer within a month, the maximum amount that can be called upon in any given hour and the minimum amount that must be scheduled by a customer "around the clock". Otherwise, SLCA/IP customers schedule electrical power to meet the needs of its retail customers.

Firm capacity and energy levels are guaranteed to the customer. If Western is unable to supply contracted amounts of firm capacity or energy from Reclamation hydroelectric resources, it must purchase the deficit from other (primarily non-hydropower) resources for delivery. Depending on the type of service offered, expense for this purchased power is either shared by all contractors, leading to a general increase in the overall rate, or it is passed through to individual customers. In addition, customers may choose to purchase some or all of this deficit on their own, in which case there would be financial impacts to the customers above and beyond those impacts shared by the CRSP customers or passed through by Western.

Power Generation Impacts

Hydropower generation analyses are based on two methodologies. The first is an economic analysis that represents the effects on a national perspective for each alternative. The results from the economic analysis provide values that reasonably represent national economic benefits. The second analysis is a financial analysis representing the impact to the wholesale rates paid by the utility customers who purchase the electricity generated by Aspinall Unit powerplants.

Economic Impacts

The impact of the alternatives on the production of power, or electrical generation, at the Aspinall Unit power system is shown in Table 8. This table illustrates the average impact over the 31-years modeled for this economic analysis.

The base year used for economic analysis purposes in this EIS is 2008 and the power impacts occur over a 31-year period. As further described in Appendix D, some additional calculations were carried out to reflect the time value of money. The power prices used in this analysis are from 2007. These values were escalated to 2008 dollars using an escalation rate of 2.2 percent. Observations occurring after 2008 were escalated by 2.2 percent per year and then discounted by 4.875 percent, the current Federal discount rate. This process places the estimated power economic impacts, which occur in different years, on a commensurate 2008 present value basis. The economic results, measured in 2008 dollar terms, are reported in the narrative and results tables which follow.

Table 8.0
Impact of Alternatives on the Aspinall Unit Power System
(Difference from No Action)

Alternative	Annual Average Economic Impact (Thousands of 2008$)	Average Annual Generation (GWh)	Power Releases (TAF)	Average Annual Non-Power Releases (TAF)
A	-$11	-1.181	-7.277	7.890
B	-$622	-9.914	-41.089	41.969
C	-$-2,050	-37.690	-140.892	142.979
D	-$484	-7.360	-31.117	31.873

For each alternative, Table 8 shows changes from No Action. Calculations were made from modeled average annual results of the economic impact, the Aspinall Unit generation, the release of water through the Aspinall powerplants (power release), the release of water that bypassed the powerplant (bypass tubes and spillway), and the total release. A negative number denotes a reduction as compared to No Action. A positive number denotes an increase as compared to No Action.

As shown in Table 8, all alternatives result in a loss in electric generation as well as an economic loss from the Aspinall power system relative to No Action when considered on an average annual basis. The economic losses recorded in column two of Table 8 are especially influenced by the “retiming” of electrical generation. Generally, all of the alternatives, to one degree or another, move water release and subsequently, electrical generation, to the spring (May). The added water release in the spring required that water

be moved from other months of the year that have a greater demand – or economic value – for electrical power.

As displayed in Table 8, the average economic impact of Alternative A is insignificant at $11 thousand when compared to the economic value of around $42 million produced by the Aspinall Unit each year. The economic impacts of Alternatives B and D are larger at $622 thousand and $484 thousand, respectively, on an average annual basis but are also considered insignificant. The impact of Alternative C, reported as an economic loss on an average annual basis of $2.050 million, is nearly a five percent reduction in economic value and is considered significant. The 30-year impact of Alternative C would be over $63 million.

The economic impact to the Aspinall power system on an average annual basis is a measure of impact that can overlook significant variations that occur on a year-to-year basis. Thirty one years were modeled for the power analysis of the alternatives. The variation among years of the economic impact within an alternative is more pronounced than the average difference between any two alternatives. Economic impacts for Alternatives A, B and D that are considered insignificant on an average basis can show significant impacts in a subset of years as compared to No Action.

Table 9 shows a summary of the results of the modeling of the alternatives on electrical generation for each of the 31 years analyzed. Annual values displayed for each of the four action alternatives as compared to the No Action alternative. As shown in Table 9, the impact of the action alternatives on electrical generation at the Aspinall Unit varies significantly among alternatives. In 1975, for example, Alternative A produces more electrical generation than the No Action alternative (approximately 14,000 MWh), while Alternatives B, C and D produce about 9,000 MWh less. In comparison, on an average basis, the alternatives all produce slightly less electricity than the No Action Alternative. Since the amount of water released in a given year is the same for all alternatives modeled, including the No Action case, the generation differences would be the result of production efficiency, i.e., releasing water through the Aspinall powerplants when the reservoirs are fuller.

TABLE 9
Impacts of Alternatives on Total Aspinall Electrical Generation by Year
(Difference from No Action)

	Total Generation (MWh)			
Year	**Alt A**	**Alt B**	**Alt C**	**Alt D**
1975	13,784	(8,816)	(8,816)	(8,816)
1976	290	2,718	13,622	2,718
1977	25,236	24,606	23,436	24,606
1978	(3,960)	34,785	87,311	34,784
1979	(15,682)	(110,449)	(77,463)	(110,449)
1980	(180)	(43,127)	(99,396)	(43,127)
1981	13,250	13,708	(13,066)	13,708
1982	(10,895)	(28,300)	(291,448)	(28,300)
1983	(2,340)	(11,489)	(23,406)	(4,429)
1984	(7,400)	(4,205)	(134,734)	(5,338)
1985	2,067	2,330	(26,014)	2,161
1986	(3,070)	(17,693)	(102,853)	(17,686)
1987	(1,953)	(490)	(4,361)	(490)
1988	3,520	9,080	27,359	3,990
1989	1,717	1,700	(9,845)	(2,431)
1990	(3,810)	(11,910)	(18,596)	696
1991	(3,632)	(13,543)	(40,046)	(5,173)
1992	(21)	(5,430)	(14,756)	560
1993	(18,183)	(20,632)	(39,960)	(16,141)
1994	16	(7,111)	(26,091)	(126)
1995	(21,537)	(10,755)	(157,020)	(11,835)
1996	4,477	(45,469)	(69,070)	(45,573)
1997	675	2,523	(85,348)	2,523
1998	(2,134)	3,183	(2,602)	3,183
1999	(13)	(13,563)	(39,460)	(7,994)
2000	(21)	4,298	(6,838)	(334)
2001	(47)	(43,290)	(6,228)	(531)
2002	19,366	15,771	16,417	18,874
2003	50,963	64,412	80,347	46,209
2004	(5,844)	13,498	41,779	(6,195)
2005	(71,258)	(103,680)	(161,232)	(67,219)
Total	(36,622)	(307,341)	(1,168,377)	(228,174)
Average	**(1,181)**	**(9,914)**	**(37,690)**	**(7,360)**

Table 10 displays the impact of the alternatives in terms of economic cost or economic value. The alternatives differ significantly from each other when looked at annually. For example, in 1978, in comparison to the No Action alternative, Alternative A decreases the value of electrical generation, Alternative B and D increase the value of electrical generation by $1.26 million and Alternative C increase the value of electrical generation by about $5 million.

TABLE 10
Impacts of Alternatives on Total Aspinall Economic Value by year
2008 Dollars (Difference from No Action)

Difference from No Action				
Year	**Alt A**	**Alt B**	**Alt C**	**Alt D**
1975	$1,649,043.44	($744,574.41)	($744,576.30)	($744,576.30)
1976	($445,804.58)	($560,867.64)	($107,327.92)	($560,867.08)
1977	$1,844,412.82	$1,796,962.53	$1,705,736.43	$1,796,961.66
1978	($222,690.11)	$1,260,991.69	$4,820,656.54	$1,260,989.39
1979	($993,932.22)	($7,261,204.67)	($4,523,834.30)	($7,261,205.03)
1980	$116,354.85	($2,516,619.69)	($6,076,651.05)	($2,516,619.25)
1981	$843,837.83	$886,874.68	($908,066.40)	$886,875.72
1982	($693,226.66)	($2,068,096.52)	($18,096,299.04)	($2,068,097.12)
1983	($141,413.45)	($722,601.02)	($1,381,020.53)	($429,663.95)
1984	($445,689.33)	($236,907.31)	($6,972,752.65)	($297,485.91)
1985	($68,616.63)	($125,902.35)	($1,605,533.75)	($136,668.54)
1986	($214,650.35)	($1,390,622.62)	($6,089,356.61)	($1,390,106.55)
1987	($98,192.42)	($41,589.48)	($305,964.36)	($41,566.36)
1988	$230,955.01	$407,206.28	$1,048,137.35	$256,430.18
1989	$92,905.80	($69,469.28)	($862,513.27)	($85,643.14)
1990	($162,958.51)	($597,131.55)	($955,909.01)	$76,281.78
1991	($176,027.75)	($714,234.43)	($2,067,896.77)	($326,745.61)
1992	$6,079.16	($332,466.64)	($1,028,165.10)	$36,504.81
1993	($734,214.32)	($828,785.33)	($1,618,107.80)	($625,551.13)
1994	$3,761.35	($476,742.40)	($1,590,130.58)	($5,412.26)
1995	($942,069.78)	($456,825.34)	($6,071,368.46)	($510,836.03)
1996	$120,867.95	($2,202,669.54)	($3,394,304.06)	($2,206,548.35)
1997	($23,613.11)	$11,545.35	($3,723,665.91)	$11,547.74
1998	($138,832.36)	$149,557.65	($127,873.65)	$149,543.02
1999	($36,425.20)	($708,437.84)	($1,834,257.18)	($465,762.88)
2000	$13,913.36	($159,791.16)	($373,465.51)	$6,690.98
2001	($2,248.41)	($1,777,892.43)	($350,989.44)	($20,619.98)
2002	$751,099.73	$630,365.26	$650,594.48	$732,627.73
2003	$1,982,426.67	$2,423,555.58	$2,943,264.53	$1,824,406.00
2004	($177,706.17)	$435,544.10	$1,298,832.53	($192,370.56)
2005	($2,275,176.01)	($3,283,608.79)	($5,213,926.40)	($2,151,539.97)
Total	($337,829.40)	($19,274,437.32)	($63,556,734.19)	($14,999,026.99)
Average	($10,897.72)	($621,756.04)	($2,050,217.23)	($483,839.58)
Percent Difference	-0.03%	-1.47%	-4.86%	-1.15%

The differences between alternatives are affected by the economic value of power. This is because generation is not valued the same in each month of the year. An alternative that produces considerably more electrical power in May, may have this gain offset by a slight decrease of electrical power in August. This is because the value of power in August is considerably higher than in May.

Impacts analyzed on an annual average basis can hide the effect of monthly changes in electrical generation. In order to release water through the Aspinall powerplants over the course of a year, the releases are patterned over the year in terms of monthly targets. The alternatives differ significantly regarding the monthly pattern over a year of water release and electrical generation. This monthly variation in releases, coupled with seasonal variations in the economic value of power, can mask detrimental economic impacts within a given year even though the average annual impact appears to be of little significance. Such monthly or annual variations in available generation could make it necessary for Western to purchase replacement power to meet contract commitments. Power revenues available for deposit in the Basin Fund could be reduced and thus impact the amount of funding available for operation and maintenance of facilities, including support for environmental programs, and also reduce repayment capability of the Basin Fund.

Financial Analysis Method and Results

Hydropower is generally less expensive to produce than alternative technologies since there is no fuel cost. The SLCA/IP rates include assistance to water development projects. Currently, about one third of future revenues projected in the SLCA/IP rate are programmed to financially assist the development and construction costs of authorized water projects.

While the SLCA/IP rate for wholesale power is relatively inexpensive, retail rates of SLCA/IP electrical coop & irrigation customers are typically higher than in privately owned utility service areas. This is the case, to a great extent, because rural areas require larger investments in transmission and distribution lines for each commercial, industrial or residential load served.

Western sells SLCA/IP electricity under long-term firm contract. It charges for capacity contracted and for energy used. These are separate charges. Often, for ease of display or understanding, Western reports a “composite” rate – a combination of the capacity and energy prices charged. The financial impacts are reported as changes in the composite rate.

The SLCA/IP electrical power is marketed on a cost-based basis. Table 11 displays the impact of the alternatives on the SLCA/IP firm-power rate. A positive number indicates an increase in the SLCA/IP rate as a result of the implementation of an alternative. A negative number indicates a decrease in this rate as a result of an alternative. The rate change in Table 11 is shown in mills (one thousandth of a dollar) per kilowatt hour. All but one of the alternatives (Alternative A) would require an increase in the SLCA/IP rate.

Table 11
Impacts to the SLCA/IP rate

Alternative	Change in SLCA/IP rate (mills/kWh)
No Action	0.00
Alternative A	- 0.03
Alternative B	0.16
Alternative C	0.53
Alternative D	0.14

Again, these numbers are based on an “all other things equal” assumption. An actual change in the SLCA/IP rate, if any, would be triggered by changes in a variety of variables, including modifications of the operation of the Aspinall Units.

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Appendix D

Economic Analysis

Estimation of Visitation and NEV

Net economic use value is a measure of the amount individuals are willing to pay, over and above the costs of participating in a recreation activity. The total net economic value is related to the number of recreationists who participate in each activity, the time of year in which they participate, and the value of each trip taken.

The study by Piper (2007, 2008), of recreation at the Aspinall Project (Blue Mesa, Morrow Point and Crystal Reservoirs) demonstrated the net economic value of recreation varied systematically with the elevation of Blue Mesa Reservoir. This recent, site specific study forms the basis for the quantitative estimates of visitation and net economic value (NEV) of recreation impact presented in this EIS.

Piper (2007) estimated a count data travel cost model using data collected in a 2004 survey administered by Munger and Vinton (2005). More specifically, he estimated a Poisson travel cost model corrected for endogenous stratification. Further details about the model can be found in the sources cited.

In the Poisson model, a response variable y_i denotes the *i*th observation of a non-negative discrete variable with n observations and x_i denotes the corresponding row of the matrix of k regressors, including a constant. The Poisson regression model specifies that y_i given x_i is Poisson distributed with the density function (1)

$$\Pr(Y=y_i) = f(y_i|\lambda_i) = \frac{e^{-\lambda_i}\lambda^{y_i}}{y_i!} \qquad (1)$$

and the mean or expected value is given by equation (2)

$$\lambda_i = \exp(x_i' \beta) = e^{\beta_1 + \beta_2 x_2 + \ldots\ldots + \beta_k x_k} \qquad (2)$$

In (1), $\Pr(Y= y_i)$ is the probability of y occurring for sample observation *i*, λ is the Poisson distribution parameter, x' is a vector of explanatory variables and β a parameter vector. The exponential form implies that a change in $x'\beta$ required to get a one unit of increase in *y* is smaller the further we move from zero. The parameters are estimated using a maximum likelihood estimator. The log likelihood function for the Poisson model is shown in expression (3).

$$\ln LF(\beta) = \sum_{i=1}^{n} \{y_i (x_i'\beta) - \exp(x_i'\beta) - \ln y_i\} \qquad (3)$$

In the econometric model he used, the log-linear visitation relationship was specified as shown in (4).

$$\ln \lambda = \beta_0 - \beta_1 \text{ TC} + \ldots \beta_n X_n , \qquad (4)$$

Equation (4) is a log-linear demand function. This demand function relates the number of trips to the recreation site taken by each household during the year (λ) to the price or travel cost (TC) and a variety of other explanatory variables. Consumer surplus is the area under the demand function (4) between a price of zero and the mean price paid by recreators.

Integrating equation (4) with respect to TC, from 0 to the mean TC, yields the per household consumer surplus during the recreation season or (5).

$$CS_{HH} = \frac{e^{\beta_0 + \beta_1 TC + \beta B_2 + \ldots + \beta_n}}{-\beta_1} \qquad (5)$$

Recall that λ is the number of trips, per household, taken to the recreation site. The consumer surplus per household per trip is then equal to (6):

$$CS = -1/\beta_1 . \qquad (6)$$

The estimated coefficients for this model and the means of the variables used in the model are shown in Table 11.

Table 2. Model Coefficients and Mean Values

Variable	Units	Estimated Coefficient[18]	Mean of Variable
constant	intercept term	-176.93580	1.0
Travel cost	Cost[19] per Trip (2004$)	-0.005768	$224.00
Age	Age of respondent (years)	-0.00231	49.85
Income	HH[20] Income (2004$)	0.00000845	$57,492.00
elevation	Blue Mesa elevation (ft)	0.023878	7492.3

During the 2004 recreation season (May through September), there were 788,625 recreational visits[21] recorded at the Aspinall Project (National Park Service 2008). Using the mean elevation for the 2004 recreation season (7491.67 ft), and the means of the other

[18] The estimated coefficients shown here are from Piper (2007) Table 6, Poisson model results for current scenario data, adjusted for endogenous stratification.
[19] Round-trip travel cost per household per trip. Travel cost components and their calculation are detailed in Piper (2007).
[20] HH is an abbreviation for household.
[21] Defined as one person taking a trip. The duration of a trip could be 1-hour or several days.

variables, the travel cost model predicts the average household visited the Aspinall Project on 2.7798037 occasions in 2004.

Based on the number of recreational visits in 2004 (788,625), the predicted number of household visits to the Aspinall Project in 2004 (2.7798037) and the mean household size (2.4), an estimated 118,207.5375 households visited the Aspinall Project in 2004.

Unlike many travel cost models, the consumer surplus per trip estimated with the Poisson model is independent of the number of trips taken. This is illustrated in equation (6). Using equation (6) and the estimated coefficient for TC, shown in Table 11, the 2004 consumer surplus is estimated to be $72.24 per person per trip (in 2004 dollars).

Discounting Procedures

The costs and benefits of most environmental policies are incurred at different times over what are frequently long time horizons. A fundamental concept in finance and economics is that the timing of benefits and costs makes a difference in the attractiveness of an investment. All other things being equal, one would prefer to receive the benefits of an investment as soon as possible and to pay the costs as far out in the future as possible. Given the choice between receiving $100 today or $100 a year from now, most people would prefer $100 today. Alternatively, if given the choice between paying out $50 today or one year from now, most of us would prefer the latter.

Because the timing of these costs and benefits differs across alternatives, responsible policy choice requires the use of appropriate techniques to allow for commensurate comparisons. Typically, the present value of the future stream of costs and benefits for each alternative is computed and the results arrayed for decision-makers.

Discounting is the methodology used for finding the present value of a cost or benefit that occurs at some time in the future. The process of “discounting” is used to make costs or benefits which occur at different points in time commensurate with each other.

Although the mechanics of the discounting process are very straightforward, the magnitude of the discount rate greatly influences the degree to which future costs and benefits “count” in the decision. As a result, the choice of discount rate is the subject of much controversy.

The literature on discounting and the choice of discount rate is rather vast. Many modern economics texts contain synopses of this literature (e.g. Tietenberg 2006). A more lengthy assessment can be found in the Environmental Protection Agency *Guidelines for Preparing Economic Analyses* (2000).

Summarizing this literature, most economists recommend the real risk-free discount rate for the analysis of environmental programs. A perplexing complication is the real discount rate is not directly observable. However, empirical estimates of the real discount rate commonly lie in a range from 1 percent to 5 percent.

The majority of water resource agencies, including the Bureau of Reclamation, are required to use the so called project evaluation rate in their analyses. The determination of this rate is specified by the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (U.S. Water Resources Council 1983). This rate is calculated annually and published in the *Federal Register*. The project evaluation rate for fiscal year 2008 is 4.875 percent.

As described, the project evaluation rate is, quite clearly, a nominal discount rate. In simple terms, a nominal discount rate is composed of two components: a real interest rate component and an inflation rate component (see note 1 below). The real interest rate is the money paid for the use of capital, expressed as a percentage per period that does not include a market adjustment for the anticipated general price inflation rate in the economy. It represents the time value change in future cash flows based only on the potential real earning power of money. The inflation rate is the percentage rate of change of the aggregate price level from one period to another.

To make this analysis consistent with the recommendations of most professional economists, all costs and benefits are inflated by an escalation rate of 2.20 percent per annum. For a nominal discount rate of 4.875 percent, this process is equivalent to employing a real discount rate of 2.617 percent (see note 1).

The base year chosen for this analysis is 2008. All economic value estimates reported in this document are measured in 2008 dollars.

In summary, the discounting process employed in this analysis conforms to the process described in U.S. Water Resource Council (1983), Environmental Protection Agency (2000) and the recommendations of professional economists. The selected base year for this project is 2008 and the estimated costs and benefits occurring in 2008 are not discounted (or escalated). All subsequent annual costs and benefits are escalated at 2.2 percent per annum and discounted back to the 2008 base year using a discount rate of 4.875 percent.

Note 1. Discount Rates—Real, Nominal and Inflation Rate Components.

A nominal discount rate (DR) is composed of two components: a real interest rate (r) component and an inflation rate component (i). The relationship of a nominal discount rate to the real interest rate and the inflation rate is shown in equation (1).

$$DR = [(1+r)\times(1+i)-1] \qquad (1)$$

where:

DR = (nominal) discount rate
r = real rate of interest

i = inflation rate

Quite often, you see this relationship incorrectly characterized as DR = r + i. However, this procedure is incorrect and, depending on the magnitude of i and r, can lead to significant errors in calculations.

Appendix E

Scoping Summary Report

Scoping Report-
Aspinall Unit Operations EIS
May, 2004

Gunnison River near Bridgeport Colorado.

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1. Introduction and Background

Reclamation is preparing the Aspinall Unit Operations Environmental Impact Statement (EIS) to describe potential effects of operation changes for the Wayne N. Aspinall Unit that are related to compliance with the Endangered Species Act (ESA). Public involvement will be an important activity in the development of the EIS. The first phase of the public involvement process is "scoping" and is designed to help determine issues and alternatives to be addressed in the EIS. Scoping is defined as "an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to the proposed action." This report summarizes the findings of the scoping period.

A draft and final EIS will be prepared to provide decision makers appropriate information and to inform the public of the proposed action, reasonable alternatives, and the impacts of the alternatives. In addition to scoping of significant issues and alternatives, key activities will include development of alternatives that support the proposed action and need, analysis of issues in the EIS, selection of a recommended plan, and preparation of a Record of Decision. Periodic meetings and mailings will be used to keep the public updated on the EIS.

The Record of Decision will be the final product prepared under this EIS. It will officially present the Department of the Interior's position on operating guidance for the Unit.

Reclamation will define the baseline for species considered and prepare a biological assessment on the preferred alternative in compliance with Section 7 of the ESA. The Section 7 consultation will cover the effect of the proposed operating criteria and guidance for the Unit compared to the baseline conditions. The Fish and Wildlife Service will prepare a biological opinion on the proposed action.

The Aspinall Unit (Unit) -- which includes Blue Mesa, Morrow Point, and Crystal Dams, Powerplants, Reservoirs and associated facilities -- is located in western Colorado. The Unit was authorized by the Colorado River Storage Project Act of 1956 along with Glen Canyon, Flaming Gorge, and the Navajo Unit. The authorization calls for meeting a variety of purposes including:

- regulating the flow of the Colorado River;
- storing water for beneficial consumptive use;
- providing for the reclamation of arid and semi-arid land;
- providing for the generation of hydroelectric power;
- providing for the control of floods; and
- allowing the Upper Basin states to develop Colorado River Compact apportioned waters.

Flow Recommendations have been developed through the Upper Colorado River Endangered Fish Recovery Program (Recovery Program). The recommendations describe the annual and seasonal patterns of flow in the lower Gunnison River, and in the Colorado River downstream from their confluence, identified as needed to help recover endangered fish.

The initial definition of the proposed action is to: develop operating guidance to implement reservoir operation changes to avoid jeopardy to endangered species while maintaining the congressionally authorized purposes of the Unit.

The need for the proposed action is defined as follows: Guidance is needed to operate the Unit to avoid jeopardy to endangered fish species while complying with the Unit's authorized purposes. The need sets the overall focus of the EIS process and is the ultimate requirement that all alternatives must satisfy. The underlying need associated with the proposed action is based on legal obligations to maintain the authorized purposes of the Aspinall Unit as well as to comply with the ESA.

There are a group of purposes and desired goals that will be addressed in alternatives. The following purposes and/or goals of the proposed actions are recognized:

- Help the state of Colorado protect/use its compact entitlement
- Operate alternatives within State water law
- Satisfy as many needs as possible with same water releases
- Protect recreation at Unit reservoirs and in the Gunnison Gorge and Lower Gunnison River
- Protect tailwater and reservoir fisheries
- Provide needed hydropower flexibility
- Provide flood control
- Provide for public input and public information concerning operations of the Unit
- Assist the National Park Service in protecting resources of the Black Canyon of the Gunnison National Park (Black Canyon)
- Allow for adaptive management as new scientific data becomes available through monitoring of endangered fish responses

The degree to which alternatives meet identified purposes provides decision makers guidance in selecting alternatives for detailed study and ultimately for selection of a recommended plan.

Primary water storage at the Unit occurs in the uppermost and largest reservoir, Blue Mesa. Reclamation manages available water at the Unit within certain sideboards that include annual snowpack conditions, senior water rights, minimum downstream flow requirements, flood control, powerplant and outlet capacities, reservoir elevation goals, fishery management recommendations, dam safety considerations, and others. Certain sideboards can be considered mandates such as honoring senior water rights and flood control, while others such as reservoir elevation criteria to reduce landslides are given a high priority. To conserve water for later use, an operational goal is to fill Blue Mesa by

the end of July. Another operational goal is to draw Blue Mesa down to an elevation of 7,490 by December 31 to provide space for the next spring's runoff and to avoid ice damage upstream.

The five generators at the three dams of the Unit are capable of generating up to 283 megawatts of electricity. Morrow Point is the powerhouse of the Unit—its generators produce twice as much electricity as those at Blue Mesa. The Western Area Power Administration markets electricity generated by the Unit in conjunction with power from Glen Canyon and Flaming Gorge Dams and other plants of the Colorado River Storage Project as part of an integrated system that provides electricity to all states of the Colorado River Basin. The upstream powerplants of the Unit (Blue Mesa and Morrow Point) are critical in that they can be operated to provide peaking power (high flexibility in release rates). Crystal Reservoir then serves as a regulation reservoir to stabilize flows to the Gunnison River.

Public recreation use of Aspinall Unit lands and water are managed by the National Park Service as the Curecanti National Recreation Area. Blue Mesa Reservoir supports around 1,000,000 recreation visitor days per year. Fishing, boating, and camping are primary recreation uses. Fishing and rafting are important recreation activities downstream from the Unit.

Approximately 3 miles downstream from Crystal Dam, the Black Canyon of the Gunnison National Park begins and stretches 14 miles along the Gunnison River. Downstream from the National Park, lands are administered by the Bureau of Land Management as the Gunnison Gorge National Conservation Area.

At the United States Geological Survey gage at the head of the Black Canyon, historical average monthly flows have been 1,320 cfs and daily flow extremes have ranged from a few days of no flows to 19,000 cfs. Another important measurement point on the river is the Whitewater gage, eight miles upstream from the Colorado River confluence and approximately 90 miles downstream from Crystal Dam. At this point the drainage area is roughly 8,000 square miles; average monthly flows are approximately 2,600 cfs, and historic extremes have ranged from 106 cfs to over 35,000 cfs. The Aspinall Unit stores water during spring runoff and releases it when needed to meet downstream needs. Unit regulation since 1969 has reduced Gunnison River flows during spring runoff and increased flows during the non-runoff months. Even with regulation, however, flows vary with the amount of snowfall. For example, annual flows through the Black Canyon averaged 396 cfs during 1977 and 2,943 cfs during 1984.

Unit operations provide flood control benefits, both upstream and downstream of the reservoirs. One of the operational sideboards for high water years is to reduce flooding through the Delta area during spring runoff. Coordination of the Aspinall Unit and Taylor Park operations reduce upstream flooding. During the winter months, Blue Mesa Reservoir is drawn down approximately 30 feet from full (7490 feet elevation) to help reduce winter flooding caused by ice jams upstream from the reservoir near the city of Gunnison.

The Unit is located 50 miles upstream from habitat of the endangered fish species; however, operation of the Unit changed the flow regime of the lower Gunnison River and to a lesser extent the Colorado River within what is now critical habitat for endangered fish. The Gunnison River provides habitat for two of the endangered fish species, the Colorado pikeminnow and the razorback sucker. The 50 miles of river downstream from Delta, Colorado, are designated as critical habitat for these species. These and two additional endangered fish species—the humpback chub and bonytail chub—occur in the Colorado River downstream from the mouth of the Gunnison River. Operation of the Unit is important in determining the flow pattern of the Gunnison River, and to a lesser extent, the Colorado River.

Since 1988, the Upper Colorado River Endangered Fish Recovery Program has worked to address endangered fish issues in the upper Colorado River. The Recovery Program is a partnership created to recover the endangered Colorado pikeminnow, razorback sucker, humpback chub, and bonytail while allowing for continued and future water development. The Recovery Program was initiated in 1988 when a cooperative agreement was signed by the Governors of Colorado, Utah and Wyoming; the Secretary of the Interior; and the Administrator of the Western Area Power Administration. Recovery Program partners include the Colorado River Energy Distributors Association, Colorado Water Congress, Western Resources Advocates, State of Colorado, State of Utah, State of Wyoming, The Nature Conservancy, Reclamation, the Fish and Wildlife Service, National Park Service, Utah Water Users Association, Western Area Power Administration, and Wyoming Water Association.

The program has 5 elements: habitat management, which includes developing river flow recommendations; habitat development; nonnative species management; endangered fish propagation and stocking; and research and monitoring. The Aspinall Unit Operations EIS will assist in addressing the habitat management element. The operation of the Aspinall Unit is a key component of the Recovery Program for offsetting adverse effects of flow depletions from the Gunnison and Colorado rivers and allowing water development in the Upper Colorado River Basin. Other elements of the Recovery Program are ongoing or planned for the Gunnison River and include the fish passage at the Redlands Diversion Dam, a fish screen on the Redlands Canal, bottomland habitat development near Whitewater and Delta, stocking, and research and monitoring.

Flow Recommendations for the Gunnison River were prepared by the Fish and Wildlife Service and the Recovery Program using the results of research and monitoring activities funded as part of the Recovery Program and are presented in the July 2003 report titled "Flow Recommendations to Benefit Endangered Fishes in the Colorado and Gunnison River". The goal of the recommendations is to provide the annual and seasonal patterns of flow in the Gunnison River and in the Colorado River downstream from their confluence to recover populations of the four endangered fishes. The degree to which Flow Recommendations are met for the Gunnison River will be modeled and measured at the Whitewater USGS gage (Gunnison River near Grand Junction). Only approximately 50 percent of the basin above this point is regulated by the Aspinall Unit, thus it is apparent that Unit operations can only partially assist in meeting recommendations.

Copies of the Flow Recommendations are available on the internet at Http://www.usbr.gov/uc/wcao/rm/aspeis/pdfs/GunnCoFlowRec.pdf.

2. Public Scoping Activities

Several methods were used to inform the public and solicit comments on preparation of the EIS. These methods included publication of a Notice of Intent in the Federal Register, press releases, preparation and mailings of information packets, meetings with interested parties, scoping announcements, and public scoping meetings.

The formal scoping period began on January 21, 2004 with the publication of a Notice of Intent in the Federal Register. The Notice described Reclamation's intent to prepare an EIS, announced public meeting dates, and solicited public comments. The original comment period was extended to April 15, 2004.

Reclamation distributed an announcement of the scoping meetings along with background information to an initial EIS mailing list of approximately 170 individuals, organizations, agencies, and Tribal governments. The announcement requested written comments as well as attendance at the scoping meetings. News releases and personal contacts were also used to notify people of the scoping meetings.

Public scoping meetings were held February 24, 25, and 26 in Gunnison, Delta, and Grand Junction, respectively. Representatives from federal, state, and local agencies attended the meetings, as well as members of the public. At the meetings, Reclamation presented background information and listened to public comment and questions. Forms were also provided for written comments. At the meetings, Reclamation offered to meet individually with groups or organizations to discuss the EIS process.

Additional meetings were held with the Fish and Wildlife Service, Western Area Power Administration, Western Resource Advocates, Colorado Water Conservation Board, Colorado River Water Conservancy District, Upper Gunnison Water Conservation District, and the Uncompahgre Valley Water Users Association.

A website has been developed to provide updated information on the EIS process (www.usbr.gov/uc/wcao/) and an e-mail address to obtain information or offer comments on the EIS has been established (aspinalleis@uc.usbr.gov).

3. General Scoping Results

Notes and transcripts from the scoping meetings are available for review at Reclamation's office in Grand Junction. In addition, written input was received from

approximately 40 agencies, individuals, and organizations and is also available for review.
The following section of this report summarizes comments and concerns associated with specific topics. The information is a compilation of information presented and no attempt is made to analyze/support/or refute the comments.

Planning considerations:

- Study area should be defined; suggestions include the entire Gunnison Basin or expanded areas to include all or portions of the Colorado River Basin.
- Time frame for analysis needs to be defined.
- Uncertainties related to climate, population growth, and socio-economic changes need to be addressed.
- Applicable laws, regulations, and contracts need to be tabulated; and type of actions requiring congressional authorization identified.
- Interrelationships of CRSP Units need to be explained.
- Adaptive management and coordination with recovery goals basin wide need to be considered.
- Existing data, data bases, and ongoing studies need to be tabulated. What resources are now monitored and what are the results?
- Will future water demands be projected?
- How is this planning effort integrated with other Basin planning efforts?
- How are the 2 targets (lower Gunnison and Colorado River) for flow recommendations to be handled?
- Gunnison River flows should be targeted; the Gunnison Basin should not be responsible for meeting Colorado River targets.

Proposed action and purpose and need:

- Several commentors stressed that the proposed action should be to recover the endangered species rather than “avoid jeopardy” under the ESA.
- Comments were made that ESA needs surpassed the need to meet other Unit purposes. Others stressed the importance of protecting Unit authorized purposes as a priority. There were also suggestions that the ESA issues and meeting traditional Unit purposes could be compatible.

Baseline (existing conditions from ESA standpoint):

- Most commentors believed the baseline should include existing water uses and agreements and should not include future or speculative projects.
- Concerning the 60,000 af subordination for the Upper Gunnison Basin, some commentors believed only that portion presently being used should be included in the baseline while others thought the total amount should be in the baseline.
- Commentors pointed out that the AB Lateral Hydropower Project should not be/should be included in the baseline.
- The role the Dallas Creek and Dolores Projects’ biological opinions play in the baseline needs to be determined.
- Full use of Dallas Creek Project water should be included in baseline.

- Some commentors believe that Aspinall Unit storage water should be used to meet senior water right needs with supplemental storage releases and this should be part of baseline.
- The 2003 Black Canyon Settlement Agreement for Black Canyon reserved water rights should be part of the baseline.
- The 300 cfs minimum flow through Black Canyon should be in baseline.
- Flows for the Redlands fish ladder should be in baseline; final plans for Redlands fish ladder, fish screen, and migration flows would be determined in EIS process.
- Hydropower contracts are flexible, so they should not be in the baseline.

Alternatives:

- Suggestions were made that alternatives should seek recovery of fish, not just avoidance of jeopardy under the ESA.
- Section 7 (a)(1) of the ESA requires Federal agencies to use its authorities to conserve endangered species—applies to other agencies with Aspinall interests—such as WAPA and NPS. These agencies should support alternatives that assist in fish recovery.
- Alternatives should include the April 2003 Black Canyon settlement agreement.
- Alternatives should protect existing uses and purposes. Alternatives should/should not include decommissioning the Unit.
- EIS should center on maximizing Unit flexibility for the benefit of all resources.
- Alternatives must protect Colorado's ability to develop compact entitlement.
- Clarify whether the EIS will cover "water marketing"; many said that it should not.
- An array of alternatives should be presented; at least one should do everything possible to meet the flow recommendations.
- Alternatives should reveal tradeoffs---use of water for flow duration vs. peak flow; peak flows vs. base flows, etc.
- An alternative addressing "water banking" is needed—would involve reducing the Redlands call to gain storage for later use.
- Hydrology modeling will be important part of alternative development and should be open and understandable to the public and agencies and organizations.
- Alternatives should address severe and multi-year droughts—will alternatives enhance performance of the Colorado River system to address severe sustained droughts.
- Flexibility should be retained to address drought periods quickly.
- Adaptive management should be designed to respond to drought periods.
- Climatic variability should be considered in alternatives; relatively short records used in EIS may not be representative of the next decades; climate change models should be referred to.
- Consideration should be given to upgrading the Gunnison Diversion Dam to accommodate higher flows—would this also facilitate run-of-river hydropower at the diversion dam itself?
- An alternative of using water "surplus" to the existing needs (spill water) to generate a spring peak would meet many of the outlined purposes.

- Water should be held back in the Unit in fall and winter for a spring peak.
- Alternatives should protect the use of the Unit as the reasonable and prudent alternative under the ESA for the Dolores and Dallas Creek Projects.
- Alternatives should be concerned with meeting Gunnison River targets, not Colorado River targets---that should be responsibility of others on the Colorado River mainstem.
- Mitigation should be included for any adverse effects on water rights, water supplies, and flooding.

Water uses and water rights:

- Aspinall water rights and decrees need to be followed. Some believe that these call for the Unit to be operated to deliver storage water, when water is available, to minimize or protect against downstream calls by senior water rights; suggestions for a solicitor's opinion on this subject were made.
- Lower flows at certain times of the year could increase "calls" on the river and harm municipal and other upstream water users; adverse effects should be addressed with mitigation plans—one idea would be providing augmentation water from Reclamation reservoirs.
- The Unit's role in meeting compact calls needs to be addressed.
- Effect of climate changes on meeting compacts should be considered.
- What will be the effect on upstream waterways such as the Taylor River?

Water quality:

- If there are reduced flows in the river at times under alternatives, what effect is there on concentrations of pollutants, including selenium?
- How do alternatives affect point source discharge permits and storm water runoff?
- Analyze effects on Blue Mesa water quality—temperature of reservoir subbasins, reservoir stratification, etc.
- How do new flow regimes affect selenium and other water quality parameters? In turn what is the effect on endangered species, point source discharge permits, and fish and wildlife resources?

Recreation:

- Recreation at Blue Mesa is very important to Colorado and needs to be protected.
- Kokanee fishery at Blue Mesa is of statewide importance.
- Impacts on Gunnison Whitewater Park, Morrow Point Boat tour, reservoir accessibility, and other recreation concerns need to be addressed.
- Analyze effects on recreation use at the reservoirs; include effects on recreation facilities.
- Gunnison Gorge recreation is very important and is affected by river flow levels.
- Timing of spring peaks early in the May 15-June 15 window would be more compatible with recreational uses along the Gunnison River, in particular high use during the salmon fly hatch that begins early to mid-June.

Fish and wildlife:

- Impacts of alternatives on the tailwater trout fishery need to be addressed.
- A flow matrix has been developed previously that includes ramping rates for flow changes downstream from Crystal Dam.
- Ramping rates for release changes from Crystal should be used that protect public safety, aquatic insects, and the trout fishery.
- Will alternatives affect the whirling disease problem in the Gunnison River?
- Effect on Blue Mesa kokanee and other fisheries—food web, interaction of fish species, water temperature, spawning in tributaries, kokanee migration, and other factors should be addressed.
- Any plans for temperature modification of releases would adversely affect reservoir and tailwater fisheries.
- Effect of any water quality changes on fish and wildlife resources should be included.
- Fishery benefits related to the Taylor Park-Blue Mesa 1975 Exchange Agreement should be protected.

Endangered species:

- Several commentors stated that recovery of the endangered fish is a priority over other Unit purposes. Others believe Aspinall Unit purposes must be protected in developing alternatives for helping to meet the flow recommendations.
- Several commentors pointed out that flow recommendations are just one way of meeting the biological needs of endangered fish and other methods should be considered in the EIS.
- Are flows targeted at Whitewater or the State Line?-needs to be clarified early in process.
- Selected alternative should satisfy the Dallas Creek and Dolores Projects' biological opinions that call for upstream storage to offset depletion impacts.
- Early agreement with the Fish and Wildlife Service on the scope and rules of the ESA consultation is needed to avoid last minute misunderstandings.
- Increasing water temperatures in the Gunnison River to benefit endangered fish should be investigated.
- Escapement of nonnative fish from the Aspinall Unit should be determined and effects of these nonnative fish on endangered fish determined.
- Depletions (131,000 af) cited in the Dolores biological opinion are not correct; 81,000 af is the correct number.

Vegetation and wetlands:

- Restoration of a natural hydrograph would help maintain the riparian corridor along the river.
- Need to address effects on near-shore vegetation and habitat along reservoirs.
- What is effect on Black Canyon riparian vegetation?

Flood control:

- Reclamation should consider floodplain management in the Delta area as a flood control alternative.
- Alternatives should not increase flows over 10,500 cfs at Delta until flood control improvements made.
- Continuing to provide flood control benefits to Delta was expressed by several commentors as a concern.
- Spring peaks have flood control benefits by keeping the channel open and discouraging development in flood prone areas.
- Flood plain should be mapped.
- Lowering the flood target (cfs) at Delta could have unintended consequences of reducing Blue Mesa storage and reducing channel capacity of the river at Delta.
- Floodplains in the Delta area and downstream provide important endangered fish habitat and adequate flows are needed to allow these floodplains to function.
- Upstream icing targets should be revisited. Can existing ice easements or new easements substitute for the winter reservoir target elevations?
- Existing reservoir operations to reduce upstream icing problems should be continued.

Hydropower:

- Some thought that hydropower is an incidental purpose of the Unit and should not direct alternative selection. Others pointed out the importance of hydropower and indicated that alternatives should protect or enhance hydropower production.
- Hydropower revenues are important for CRSP and participating project repayment and for assisting in funding the Recovery Program --- these revenues should be protected.
- Cumulative impacts on hydropower due to operation changes at CRSP reservoirs need to be presented.
- Crystal Dam's role as a reregulating reservoir should be continued; only Morrow Point and Blue Mesa should be used for peaking.
- Power generation model of WAPA should be used in EIS process.
- If there are hydropower losses, consider re-pricing hydropower to more closely reflect the market value of peaking power so as to offset any economic losses.
- Also consider as an alternative a pumped storage peaking facility at one of the reservoirs. This would offset losses and increase flexibility.

Maintenance:

- Effect of flow recommendations (spring peak) on the Gunnison Diversion Dam should be analyzed.
- What are long-term maintenance needs for the Unit and how do they fit with alternatives?

Socioeconomics:

- Importance of the Unit for hydropower and recreation and related economics was pointed out.
- What method will be used to analyze impacts-will "Principles and Guidelines" be used?
- Will alternatives require cost-reallocations for the Unit.
- Will alternatives affect property values?

Tribal issues:

- Ute Mountain Ute Indian Tribe owns land south of Blue Mesa; will reoperation affect water rights; how are people's water rights and uses affected?

Air Quality:

- Will more "flats" be exposed to wind erosion at Blue Mesa—what is effect on air quality of alternatives?

Black Canyon of the Gunnison National Park:

- Water rights for the Park need to be addressed in alternatives. Since settlement of the Black Canyon water right is in litigation, how will it be handled in hydrology modeling?
- April 2003 settlement agreement should be included in all alternatives.
- What are the effects of the alternatives on the resources of the Black Canyon?
- Some thought the alternatives should be designed to help protect the Park and meet Park purposes.
- Consider effects on sediment transport, riparian vegetation, fisheries, food webs, visitor use, river access, and anchor ice formation.

Gunnison Gorge Conservation Area:

- The effect of alternatives on recreation, natural resources, and economic benefits of the Gunnison Gorge needs to be evaluated.
- Tailwater fishery in the conservation area should be protected.

Curecanti National Recreation Area:

- The recreation and associated economic benefits of the reservoirs are very important and should be protected.
- Effects on recreation, recreation facilities, fisheries, and cultural and paleontological resources need to be addressed.

Transmountain Diversions:

- One group pointed out that Colorado's compact water is for use in all of Colorado, including the Front Range.
- Others stressed that EIS alternatives should not "set aside" any specific amount of water available for future use, including Front Range use. The EIS analysis should show the effect of alternatives on "water yield" of the Unit.
- What cumulative impacts relate to potential transmountain diversions?

Programmatic Biological Opinion:

- A PBO is very important to water users in the Gunnison Basin and should be part of or coordinated with the Aspinall EIS process.
- A PBO would benefit both federal and private interests.
- A PBO would replace or supercede the Dallas and Dolores biological opinions.

General:

- Improve notification of the public; present public information in a manner that lets the public know how they may be affected; need to keep the process, including water modeling, an open process.
- Reoperation offers the opportunity to sustainably support both the ecology and biota of the Gunnison Basin as well as the needs of the people in the region.

4. Input from agencies and organizations

Agencies and organizations provided comments and are summarized in the following paragraphs:

Senator Allard: Operation of the Aspinall Unit is critical to irrigation, recreation, drinking water supplies, and protection of Colorado's interests in Compacts. Alternatives should protect historic hydropower capacity and water storage for multiple uses. Alternatives that use "spill" water can meet many needs, including endangered fish needs and Black Canyon National Park needs.

Fish and Wildlife Service: The Service recommends that the proposed action clearly go beyond "avoid jeopardy" and should provide flows to achieve species recovery. An essential element of the Recovery Program is to provide and protect instream flows and providing adequate flows from the CRSP system is essential to the overall recovery of the endangered fish. Existing and future water uses rely on the success of the Recovery Program.

Section 7 (a)(1) of the ESA requires Federal agencies to utilize their authorities for the conservation of endangered species and this section applies to other agencies with interests in the Aspinall Unit operations, for example the Western Area Power Administration and the National Park Service.

Reclamation should examine alternatives that increase water temperatures in the Gunnison River. The flooding issue at Delta should be carefully investigated; risks determined; and solutions investigated with the goal of having adequate flows for floodplain habitat to function. Reclamation should review Blue Mesa "icing targets" to allow additional fall/winter water storage. Nonnative fish escapement from reservoirs should be investigated and effects on listed fishes presented.
The Service recommends that during the EIS process the Aspinall Unit be operated in a manner that resembles the flow recommendations.

The EIS process should evaluate how alternatives would offset impacts of the Aspinall Unit and other projects that rely on the Aspinall Unit for ESA compliance, such as the Dallas Creek and Dolores Projects.

Effects of alternative flow regimes on selenium concentrations (and other parameters) should be evaluated as to effects on attainment of water quality standards, point source discharge permits, selenium concentrations in critical habitat, and fish and wildlife resources.

National Park Service: Future operations should adequately protect resources of the Black Canyon National Park and Curecanti National Recreation Area. Reservoir issues that should be considered in EIS include: effects on upstream icing, fish populations, water temperature in subbasins of Blue Mesa and related food web and fishery resources, water and land based recreation, location of tributary inflows at different reservoir levels, cultural and paleontological resources, visitor facilities, and Morrow Point boat tour operations. Gunnison River issues include: sediment transport, fisheries and food web, riparian vegetation dynamics, visitor use and access, and anchor ice formation.

NPS wishes to participate in development of the baseline and alternatives and in development of ESA documents. Concerned with how the April 2003 Black Canyon Agreement will be handled in the No Action Alternative. EIS should clearly present operational criteria to be used to meet the agreement. Action alternatives should include a range that fully meets the needs of the endangered fish while attempting to meet Aspinall Unit purposes. Alternatives should address meeting average peak flows and instantaneous peaks. Need to keep in mind that final quantification and resolution of the Park's reserved right may affect operations.

Western Area Power Administration: WAPA believes that Reclamation should use the EIS process to identify ways of meeting purposes of the EIS without affecting hydropower. Western and their contractor Argonne National Lab have done an analysis that shows Gunnison River flow recommendations can be met using "spill" water in wetter hydrologic conditions; this analysis needs to be refined so that it can be developed into the preferred alternative.

The 2003 Black Canyon settlement agreement should be included in all alternatives.

Operating practices have developed over time, for example flow regimes to protect brown trout spawning. The No Action alternative should provide a range of operational guidelines, including the undocumented operational practices to make it clear that the impacts of No Action are variable, depending on the use of unofficial operating practices.

Cumulative impacts of restrictions of CRSP reservoirs on hydropower need to be analyzed.

Flow recommendations allow considerable flexibility in achieving targets; this flexibility should be recognized in alternatives. WAPA encourages Reclamation to develop alternatives without strictly adhering to the example described in the flow recommendations.

WAPA requests that they be a co-consultant on ESA issues and utilize WAPA's technical expertise in negotiating the reasonable and prudent alternative, conservation measures, and "take" provisions.

According to the NOI, Reclamation is attempting to "avoid jeopardy"; the flow recommendations are a contribution to "recovery". Therefore WAPA believes that Reclamation is not required to strictly meet all of the flow targets.

Bureau of Land Management: The Gunnison Gorge National Conservation Area downstream from the Aspinall Unit is a valuable recreation resource and is important to the local economy. BLM has previously provided input on the relationship of river flows to recreation and natural resources.

National Oceanic and Atmospheric Administration: The EIS should assess the implications of climate variability and long-term trends in climate for meeting the goals of Aspinall operations. Effects of long-term droughts need to be considered and alternatives should allow for adaptive management to account for water conditions that are outside the boundaries of historical data. Flow recommendations are based on a relatively short period of record; using a longer record and consideration of climate variability may be beneficial.

Referenced some studies that indicate a trend toward lower and earlier runoff conditions and this should be considered in alternative development.

Environmental Protection Agency: The purpose for the proposed action should be to meet ESA requirements. The Congressionally-recognized priority under the ESA takes precedence over other authorized purposes. The baseline for the project should not include future water depletions such as the AB Lateral Project or "60,000 af" subordination.

Ute Mountain Ute Indian Tribe: Effects of operation changes on junior water rights and all water users in Basin must be considered in the EIS.

General Assembly-State of Colorado: Expressed concern that new operations could adversely affect water storage benefits and hydroelectric supplies. Use of "spill" water for spring flows can meet endangered fish needs, protect Aspinall Unit purposes, and comply with the April 2003 Black Canyon settlement agreement.

State of Colorado (Water Conservation Board, Division of Wildlife, and Division of Water Resources): Aspinall Unit is invaluable resource to Colorado-purposes of the Unit including river regulation, water storage, compact development, etc.

must be protected. Hydropower revenues from Aspinall are valuable for recovering costs of CRSP and participating projects; also revenues help fund Recovery Program. Colorado feels it is imperative that this EIS strive to protect all the authorized purposes of the Unit and the delicate balance that exists among those purposes.

The authorized purposes must remain the highest priority and the EIS should center on maximizing Unit flexibility for the benefit of all resources. No alternative should preclude Colorado from developing its compact-entitled water.

The April 2003 Black Canyon settlement agreement must be included in alternatives; settlement will also help endangered fish.

Concerning flood control, Colorado expects the 10,500 cfs limit at Delta described in the April 2003 agreement to be honored until appropriate flood protection improvements are made. Winter "icing" targets presently used are appropriate.

Colorado urges Reclamation to use the power generation model of WAPA in the EIS process and to consider modeling work performed by Argonne Labs that emphasizes combining "spill" water into spring peaks. Colorado also will use its Colorado Decision Support System models to assist in the EIS.

Impacts of alternatives on the downstream Gold Medal fishery and the reservoir fishery should be evaluated. Entrainment, species interactions, limnological changes, and kokanee migration are some of the reservoir factors to be analyzed.

Effect of alternatives on Aspinall yield should be determined.

Modeling of the baseline condition is an important step. All current uses and exchange agreements should be included in baseline. Water presently used under the 60,000 af subordination should be included as should flows for the Redlands fish ladder (subject to plans as they may be modified in EIS process). Minimum Black Canyon flows of 300 cfs should be included and unadjudicated rights should be included/excluded in a consistent manner.

Colorado has not seen evidence that temperature modification structures at Blue Mesa would be useful or necessary for endangered fish recovery. Such modifications would require significant structural changes and may have significant detrimental effects to reservoir and river fisheries. Reservoir stratification could be adversely affected to the detriment of the Blue Mesa kokanee fishery which is of statewide importance.

The Dallas and Dolores Projects biological opinions need to be considered in the process; the Aspinall Unit is not the only source of water referred to in those opinions. On a related topic, depletions from the Dolores Project average 81,000 af compared to 131,000 projected in the Dolores biological opinion.

EIS should focus on target flows at the Whitewater gage; these flows will provide benefits to endangered fish in the Colorado mainstem, but the target should be the lower Gunnison. The Gunnison Basin should not be responsible for meeting Colorado River flow targets. The Recovery Program has agreed that upstream flow recommendations (15-mile reach) will be the controlling flow recommendations for the Colorado River and therefore the EIS should concentrate on flows for the lower Gunnison.

The proposed Programmatic Biological Opinion would supercede existing opinions on Dallas and Dolores Projects.

Operational flexibility should be maintained in alternatives to allow for adaptive management. Decommissioning should not be included in alternatives.

Solicitor interpretation of decrees and supporting documents is needed to determine the Unit's role in protecting water users from administrative calls.

Alternatives should not limit the Unit's ability to respond quickly to drought periods.

City of Delta: The City is concerned with high flows that damage public and private property. The City begins spending money for flood protection when flows reach 10,000 cfs. Alternatives that cause risk and harm to citizens should not be considered reasonable alternatives—mitigation and protection measures should be evaluated.

The City is also concerned about any alternatives that adversely affect existing or future water supplies/water rights and related socio-economic values for users in the Basin and about any adverse effects on recreation/fishing.

Better notification of public meetings is needed.

Delta County Commissioners: The Commissioners want alternatives that include adequate flows for the trout fishery and river rafting, while allowing adequate water storage to support agriculture and future domestic uses.

Cities of Montrose, Ouray, Ridgway, and Olathe: Effects on municipal water supplies and water rights must be addressed in EIS process. Lower flows at certain times of the year may lead to increased "calls" on the river and could affect municipal supplies. Similar effects could occur to other water users. Adverse effects should be addressed with appropriate mitigation; one example would be setting aside augmentation water in Reclamation reservoirs.

Colorado River Water Conservation District: The District stressed that the primary purpose of the Aspinall Unit is related to regulating the flow of the Colorado River, storing water for beneficial consumptive use, making it possible for the states of the Upper Basin to utilize, consistently with the provisions of the Colorado River Compact, the apportionments made to and among them in the Colorado River Compact

and the Upper Colorado River Basin Compact. The District believes that EIS alternatives must completely protect compact purposes.

The District recommended that certain existing commitments need to be in the baseline of the EIS: Taylor Park Exchange Agreement and Taylor refill decrees; winter reservoir targets to reduce ice flooding; downstream flood control; operations to serve as reasonable and prudent alternative for Dallas Creek and Dolores Projects under the ESA; operation according to water rights and satisfying water needs of downstream seniors; and protection of recreation and its economic benefits.

The District believes that Aspinall Unit rights and decrees call for operations that, insofar as available, satisfy prior decrees downstream from the Unit. A change in the operation of the Aspinall Unit which alters the historical river call regime on the mainstem of the Gunnison will have major impacts on virtually every water user in the Gunnison Basin with water rights junior to the 1905 priority of the Redlands senior right.

The EIS needs to address operations of the Redlands fish ladder and fish screen and any impacts on water users needs to be mitigated.

The "marketable yield" concept for Blue Mesa is fictional. The reservoir has an available yield which covers all uses and there is no separate "marketable pool." After the EIS Record of Decision has been completed and a Gunnison River Basin Programmatic Biological Opinion implemented, Reclamation can then, and only then, determine what amount of the Unit yield (beyond the relatively small amount of existing and foreseeable future in-basin contracts) may be marketed. As discussed previously though, all Aspinall Unit contracts are subject to the primary purpose of meeting compact demands.

The District stressed the importance of a Programmatic Biological Opinion to the Gunnison Basin.

Uncompahgre Valley Water Users, Tri-County Water Conservancy District, and Redlands Water and Power Company: These groups supported comments of the Colorado River Water Conservation District and expressed concern that Reclamation may have an overly broad view of its discretion in Aspinall Unit operations—the baseline should accurately address existing operational commitments made to congress, states, water users and state courts. Unit purposes need to be protected and the primary purpose is river regulation, which means storing water in times of high flows and releasing it when there are shortages. This river regulation function needs to be in the baseline.

Ridgway Reservoir operations should not be affected, since the Aspinall Unit provides ESA "mitigation" for Dallas Creek Project depletions.

Modeling of the river system should use full Gunnison Tunnel and M&D Canal capacities during the irrigation season; and Ridgway should be shown to simulate the maximum exchange of the M&I pool for the entire study period, and not be limited to

historical demands. Redlands diversions should be shown at the maximum divertible under its water rights.

The baseline should reflect the terms of water decrees, particularly Case CA 5782, that indicate that Crystal releases be made "insofar as available, be in such quantity as will satisfy at all times prior decrees from said Gunnison River below the Crystal Dam when commingled with the natural accretions in the channel of said river." In the Districts' view, the term insofar as available means that Reclamation is obligated to make releases from the Unit to satisfy downstream seniors, unless the water surface elevation at Blue Mesa is below the minimum necessary to operate the Blue Mesa powerplant. Recent operations do not represent an appropriate baseline because operations have not met these obligations.

Alternatives should include something similar to the 1995 fish ladder agreement and a similar agreement should be extended to the entire year.

Alternatives should not make up endangered fish flow shortages downstream in the Colorado River; the Aspinall Unit has enough to do as the reasonable and prudent alternative for Gunnison Basin Projects without having to make up for failures by Denver and the Colorado Big Thompson Project to mitigate their transmountain depletions.

A Gunnison PBO process should be initiated and run concurrently with the Aspinall EIS.

Setting aside a portion of Aspinall Unit water for future marketing is premature and not supported by the NOI of the EIS.

Upper Gunnison Water Conservancy District: Reclamation should clarify whether the proposed action should avoid jeopardy or strive for recovery of endangered fish. Improved accuracy in measuring water storage in Blue Mesa is needed. The role of the Unit in meeting compact deliveries needs to be considered in alternatives. A Gunnison Basin PBO should be integrated into or coordinated with the EIS process and alternatives should be designed to serve as a reasonable and prudent alternative for all Gunnison basin depletions. Existing commitments should be recognized and maintained in the process and in the baseline; for example the Taylor Park Exchange Agreement, the 60,000 acre-foot subordination, protection from downstream calls, and reservoir targets related to ice-flooding.

Dolores Water Conservancy District: Under the 1980 Dolores Project biological opinion, the reasonable and prudent alternative (under ESA) consists of releases from CRSP reservoirs, historically the Aspinall Unit. The District seeks assurance that the EIS will continue to include releases from the Aspinall Unit to serve as ESA coverage for the Dolores Project. The EIS should not preclude Colorado from developing its compact water and, specifically, should not preclude the ability of Dolores and San Miguel Basin water users from using the Recovery Program as a reasonable and prudent alternative for depletions.

Southwestern Water Conservation District: The EIS should not preclude, and in fact, should enhance Colorado's ability to use its compact water. Flexibility in alternatives is needed to address evolving understanding of fishery needs. Existing and future depletions in the Dolores and San Miguel Basins should continue to be able to depend on the Recovery Program for ESA compliance and releases from the Aspinall Unit should continue to provide the reasonable and prudent alternative for the Dolores Project.

Early agreement with the Fish and Wildlife Service on the scope of the EIS and the rules of ESA consultation are essential to avoid later misunderstandings.

ColoradoTrout Unlimited: The proposed action should result in full implementation of flow recommendations. Alternatives should be designed to conserve endangered species, not merely avoid jeopardy. The definition of the proposed action should be amended to remove any suggestion that the Unit's authorized purposes must be maintained at the expense of complying with ESA obligations. Reservoir target goals and existing operations need to be revisited in developing alternatives to conserve endangered fish. EIS should evaluate effects of alternatives on the trout fishery.

The baseline for the EIS should not include speculative projects such as the AB Lateral Hydropower Project and undeveloped portions of the 60,000 acre-foot subordination for the upper Gunnison Basin. The EIS must be clear that baseline conditions are not immutable and may have to be altered to comply with the ESA.

Water rights for the Black Canyon of the Gunnison National Park need to be addressed in the EIS process.

Grand Valley Anglers, Trout Unlimited: Crystal reservoir should continue to reregulate peaking releases from Morrow Point and Blue Mesa. Ramping rates for release changes from Crystal should be planned in coordination with the Colorado Division of Wildlife to protect public safety, aquatic insects, and the fishery. Peak releases in the early part of the spring peak window of May 15 to June 15 would be more compatible with fishing recreation than in the later half of the window. Fishery benefits of the 1975 Taylor Park-Blue Mesa Exchange Agreement should be protected.

Western Resource Advocates[22]: Believes Reclamation must analyze alternatives that meet the flow recommendations, not merely avoid jeopardy. The "need" for the EIS should be revised to reflect the true aim of the EIS—to promote conservation and recovery of the endangered fish. Reclamation should not be constrained by other Unit purposes from assessing alternatives to meet flow recommendations.

The baseline for the study is important and should only include existing water uses. Target reservoir levels and release schedules need to be re-examined in light of the need to benefit the endangered fish.

[22] Including The Nature Conservancy, San Juan Citizens Alliance, Colorado Environmental Coalition, and Audubon Colorado.

Modeling of operations is critical to the study and this should be an open process. Dallas Creek and Dolores Project biological opinions and water for the Redlands fish passage need to be considered in the EIS.

High Country Citizens Alliance[23]: Reclamation's obligation to ESA goes beyond avoiding jeopardy, should use operations for endangered fish recovery. Concerning flood control, there are alternatives other than limiting spring peaks—for example the channel at Delta could be deepened and banks modified.

Filling Blue Mesa should remain an operation goal; recreation at Blue Mesa is very important to the economy of Gunnison. The baseline should include existing uses and agreements; existing hydropower operations can be modified and are not part of the baseline. Commitments in the Dallas Creek and Dolores Project biological opinions should be included in the baseline.

Winter elevation target for Blue Mesa should be revisited. Speculative projects should not be included in the baseline.

Living Rivers: The EIS should consider effects on the Black Canyon of the Gunnison National Park and explain how operations should be managed to ensure compliance with the non-impairment provision of the NPS Organic Act. Non-native fish need to be addressed in the EIS and alternatives that eliminate predation by non-native fish need to be considered. A programmatic EIS that analyzes the dysfunction of the critical habitat of the Colorado River basin is needed rather than piece-meal approach of separate EIS's on CRSP Units.

Water quality must be addressed including the effect of motorized boating on water quality. Decommissioning the Unit must be considered as an alternative in the EIS because it meets the definition of reasonable and practical under NEPA.

Black Canyon Chapter Audubon: Implementing flow recommendations will benefit other wildlife in addition to endangered fish species. Changes in historical water use patterns may need to be investigated as part of alternatives.

Center for Native Ecosystems: Stressed that EIS should seek to recover the endangered fish species and other native species. Recovery should be emphasized over "avoiding jeopardy." Timing of releases and water quality should be carefully considered. The baseline should not include speculative projects.

Colorado River Energy Distributors: The EIS must recognize the benefits of hydroelectric power and assess impacts of alternatives on hydropower. Modeling by Argonne National Labs has shown that spring peak flows developed from surplus water

[23] Including Sierra Club, Western Colorado Congress, San Juan Citizens Alliance, Western Slope Environmental Resource Council, and Colorado Rivers Alliance.

could be periodically available to endangered fish without dramatic reoperation of the Unit.

Social and economic effects of any hydropower losses need to be addressed. Alternatives should maintain the multiple benefits of the Unit

Implementing the flow recommendations outright should be only one alternative considered in the EIS process, while other alternatives must consider the role of separate habitat management methods either solely or in conjunction with implementing the flow recommendations. Reliance on river flows for endangered fish recovery should not be made to the exclusion of other recovery methods, particularly if such river flows cannot be implemented without adversely affecting operation of the Unit for its authorized purposes, including hydropower generation.

The EIS should recognize the April 2003 Black Canyon water right settlement agreement; it should not seek to override or supplement the agreement to the detriment of hydropower. The settlement agreement can adequately protect the Black Canyon and avoid jeopardy to the endangered fish without disrupting the authorized purposes of the Aspinall Unit.

Platte River Power Authority: Aspinall Unit hydropower operations are critical to communities served by Platte River and impacts of alternatives on hydropower need to be carefully considered.

Palmer Divide Water Group: On behalf of a coalition of Front Range water providers, stressed that Colorado's compact water is to benefit all of Colorado, including the eastern slope and that water imports are an alternative to drying up eastern slope agriculture. The EIS should consider flexibility in flow regimes that allow for future depletions. Inter-basin cooperation and collaboration are needed for Colorado to use its compact.

5. Cooperating Agencies

Several agencies and governmental organizations requested to be cooperating agencies during the scoping process:

National Park Service
Western Area Power Administration
Colorado Department of Natural Resources
Southwestern Water Conservation District
Platte River Power Authority

Other agencies such as the Fish and Wildlife Service and Bureau of Land Management are considering cooperator status. Cooperating agencies are agencies with special expertise or authorities that can assist Reclamation in the EIS process.

6. Discussion of Scoping Results

The Aspinall Unit is a large multi-purpose water project that presently provides a variety of significant benefits to the public. As a large water project, it has also resulted in significant changes and impacts to the natural environment. With this in mind, the two primary concerns from the formal scoping process were not surprising: 1) the existing and future traditional benefits and uses of the Unit should be protected in the EIS process, and 2) the EIS process should be used to restore river conditions to a more natural condition and assist in endangered species recovery.

Agencies, organizations, and individuals are often focused on a particular resource or special interest and this is reflected in the scoping input. Some entities stress the priority of endangered species recovery, others protection and use of water supplies, others hydropower, and still others recreation and fish and wildlife.

From the scoping input, an idealistic preferred alternative would be one that complied with the Endangered Species Act, assisted in the recovery of endangered species, and continued to protect the multiple benefits of the Aspinall Unit. While such an alternative may not fully exist, it should be kept in mind as a general goal.

There are general concerns from the scoping process regarding the EIS process that need to be addressed:

- The process should be open and understandable to interested parties.
- Hydrology modeling is a key activity in developing and evaluating alternatives and this modeling should be presented in an understandable fashion, coordinated with key interests, and should be periodically reviewed by interested parties.
- The purpose of the proposed action--“avoid jeopardy”--needs to be clarified to see if it limits alternatives that “recover” endangered species.
- The legal or policy role of Aspinall Unit water rights and decrees in reducing water right calls by downstream seniors must be determined.
- The role of the Unit in meeting Lower Basin compact demands needs to be addressed.
- The balance and legal requirements between meeting traditional authorized Unit purposes and Endangered Species Act requirements need to be determined.
- At this time, the Black Canyon of the Gunnison reserved water right has not been finalized; how to address this in modeling of alternatives needs to be discussed.
- The role of the Dallas Creek and Dolores Project biological opinions in alternative formulation needs to be determined.
- A programmatic biological opinion to provide ESA compliance to Gunnison Basin water users is very important to a variety of interests and the relationship of a PBO to the EIS needs to be agreed upon.

The NEPA process is well suited to addressing concerns outlined in the scoping process.

Under NEPA a proposed action and purpose and need should be clearly identified. Of importance, a range of alternatives should be developed and significant issues identified during scoping analyzed prior to decision making. Public and agency participation and input should be considered throughout the process.

6. Summary

A public scoping process was conducted on the Aspinall Unit Operations EIS. Information collected will assist Reclamation in the development and analysis of alternatives and the identification of significant issues. Issues were identified that need to be resolved early in the process. Ideas for alternatives were also presented. There is strong public and agency interest in the operation of the Unit because of its importance in water development and use in Colorado as well as its importance to recreation, regional economic benefits, and in the potential to benefit endangered species.

Appendix F

National Park Service Analysis of Aspinall Reoperation Alternatives (Black Canyon)

NATIONAL PARK SERVICE ANALYSIS OF ASPINALL REOPERATION ALTERNATIVES

INTRODUCTION AND OVERVIEW: The Black Canyon was formed by the erosive power of the flowing water of the Gunnison River. Runoff from melting snow resulted in a spring-season peak flow that (to annually varying degrees) applied the power that locally displaced sediment from debris flows encroaching from side canyons and put into motion silt to large cobble-sized particles stranded within the alluvial portions of the Canyon. These same erosive flows inhibited herbaceous and woody vegetation from establishing itself on the banks and alluvial bars of the river. In any given year between 5 and 65 percent of cobble-sized particle was mobilized (Figure 1). Sediment transport and particularly movement of the cobble-sized particles is the linchpin environmental process of channel formation and maintenance in Black Canyon.

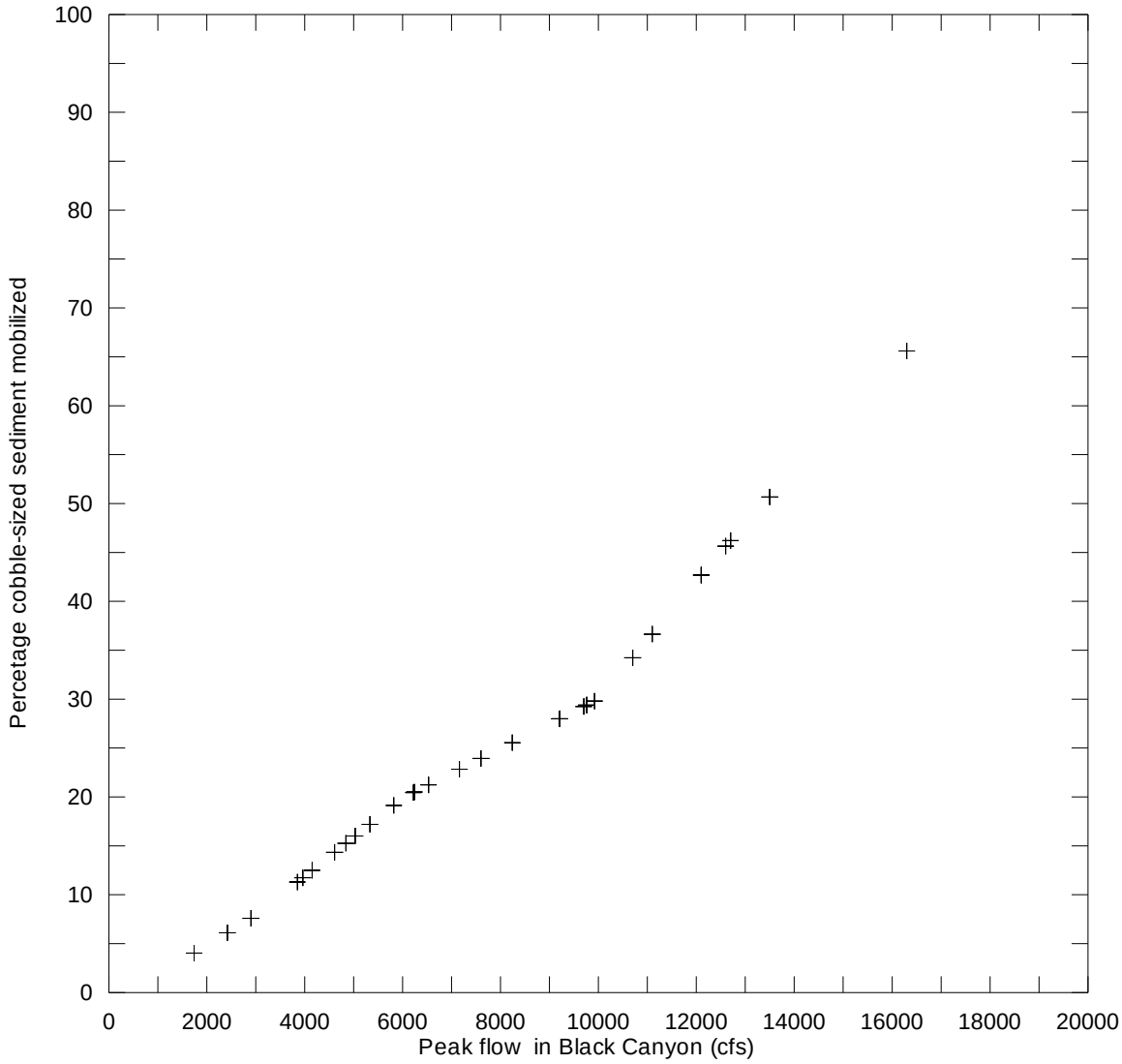

Figure 1. Sediment mobilization of the D84 fraction (cobbles) as a function of peak flows

Regulation of the river by the Aspinall Unit (Aspinall) has truncated the peak flows and hence truncated the power of the river to move sediment. Prior to regulation, alluvial reaches were characterized by "intermittent sediment transport, storage and remobilization" (Elliott and Hammack, 1999). Presently, sediment inflow and storage continue as always, it is remobilization that is impacted.

The dynamic state characterizing the ecology of Black Canyon is a condition wherein herbaceous and woody plants continuously seek to colonize alluvial bars. The counter-acting force prohibiting colonization of the cobble bars is peak and recession flows that remove the vegetation by scour and/or inundation. River regulation has not changed the prevailing dynamic of vegetation colonization. River regulation has changed conditions of control. Regulation by Aspinall truncated the peak flows resulting in less surface scour, less water seepage into alluvial deposits, and a vegetation succession on the drier land from moderately wet to arid species. Friedman and Auble (1999) show that peak flows approaching 14,000 cfs remove encroaching woody and herbaceous vegetation by scour from approximately 65 percent of the alluvial bottomland (Figure 2). The process of sediment stabilization with vegetation encroachment is slow but inexorable.

The net result of regulation is to create a condition where the alluvial bottomland is stabilized and dried, and the percentage of bottomland vegetated by arid species has increased from 1 in 1966 to 10 percent in 2005.

The principal evaluation herein is a comparison of five alternatives for the reoperation of Aspinall. NPS management policies require that NPS maintain to a natural condition the resources it manages, and in those locations where the natural condition does not exist, policy requires NPS managers to restore the environment to the closet approximation of natural conditions that is attainable (NPS,2006). That guideline is herein employed. The natural condition of the Black Canyon was characterized by frequent scouring and mobilization of sediments that kept the river corridor relatively free of woody and herbaceous plants.

NATIONAL PARK SERVICE REQUIREMENTS AS A COOPERATING AGENCY
National Park Service, Director's Order #12 Conservation Planning, Environmental Impact Analysis, and Decision Making (DO 12) establishes format and structure to be utilized by NPS for presentation of comparison(s) for alternatives prepared under NEPA. DO 12 specifies that alternatives be evaluated in terms of factors termed context (local or regional), duration (short-term or long-term), intensity (negligible, minor, moderate, major), and type (adverse, beneficial). Definitions for these factors are derived within the subject-matter of the specific Environmental Impact Statement (EIS). The factors of context, duration, intensity and

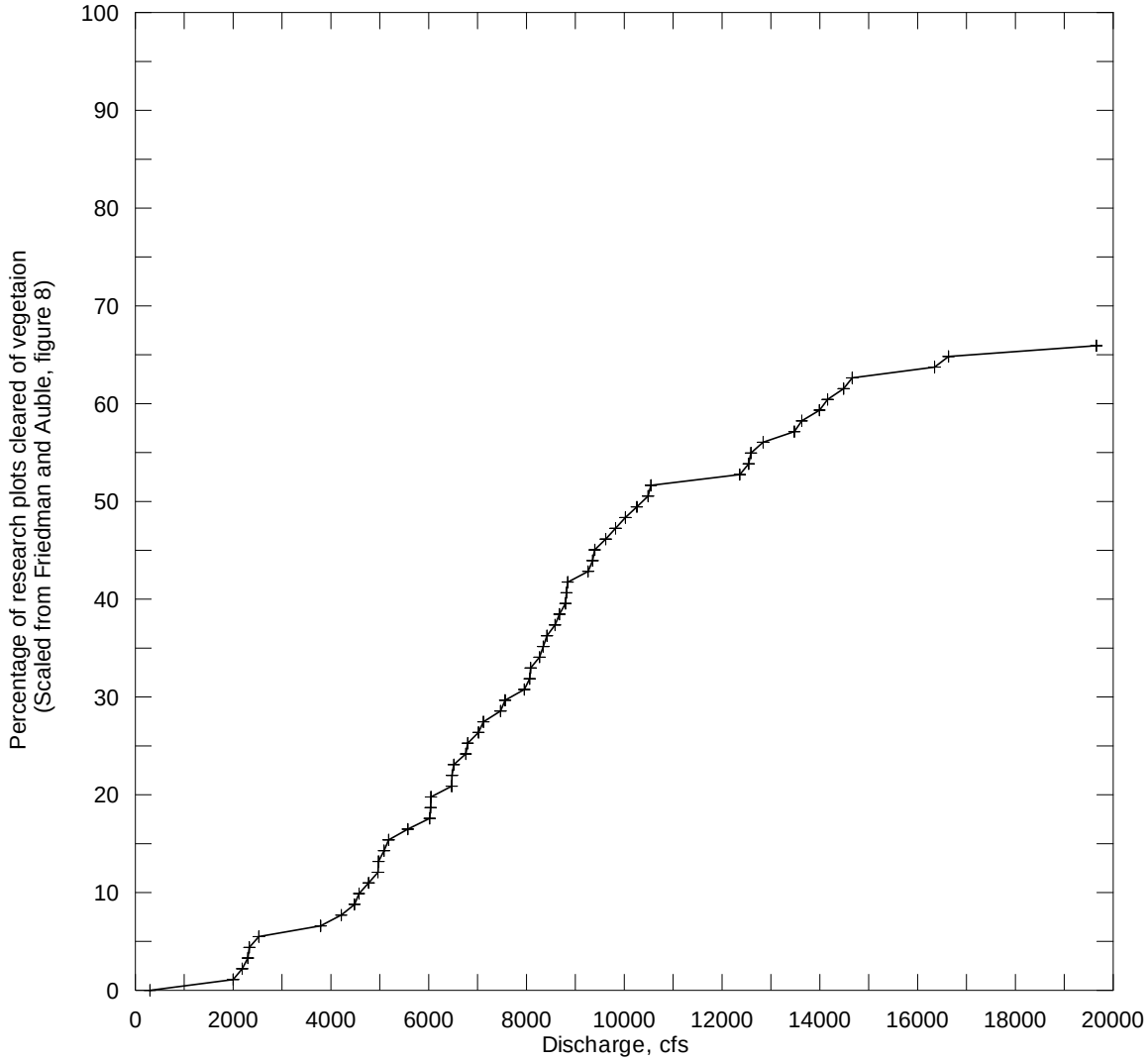

Figure 2. Percentage of bottomland scoured of colonizing woody vegetation, Warner Point Reach, Black Canyon of the Gunnison National Park.

type are utilized in concert; one factor does not stand alone. Typically, the No-Action alternative is evaluated, the action alternatives are evaluated and the results of the No-Action and action alternative evaluations are compared one by one. The No-Action is the current condition, and the action alternatives are the proposals.

The riverine environment of Black Canyon is impacted by 40 years of operation of the Aspinall Unit. Under this circumstance, a pre-impoundment standard will be incorporated in the evaluation. This affords a metric for determining how closely each operation governed by an action-alternative would come to objectives outlined in NPS policies. The preimpoundment period is defined as the period 1934 through 1964, or approximately the period when Taylor Park Reservoir is in place, but the Aspinall Unit is not.

Action alternatives are compared to the No-Action. This affords a measure of how each operation as governed by an action alternative impacts the current condition of the resources of Black Canyon.

NEPA DEFINITIONS: CHANNEL MAINTENANCE SEDIMENT TRANSPORT

Context**:** Context is defined in terms of the Reach Mobilization (Dubinski and Wohl, 2007). Context is defined such that if the change in the rate of Reach Mobilization is less than or equal to 50 percent, then the context of the impact is local. If the change in the Reach Mobilization is greater than 50 percent then the context of impacts is regional. About 10 of the 13 miles of river bottomland within the boundary of the National Park are alluvial in nature to some degree (Elliott and Hammack, 1999). The alluvial section is the region of Black Canyon most affected by Aspinall regulation.

Duration**:** Flow duration is used to define whether anticipated duration of impacts is short-term or long-term. Key peak flows necessary for protection of NPS resources are 10,000 cfs, 6,000 cfs and 3,000 cfs (see Figures 8 and 9 in Elliott and Hammack, and Dubinski and Wohl, 2007). Determination of duration utilizes the change in percentage of time the key environmental flows occur.

Elliott and Hammack (1999, p. 24) state that "break up and entrainment of the relatively coarse streambed surface or pavement, in a gravel/cobble stream periodically is necessary to adjust or maintain channel dimensions and to entrain the underlying gravel, sand, silt and clay." The relatively coarse-sized material is the size termed cobble (by strict definition a cobble is a particle with diameter 64 to 264 mm, or about 2 ½ to 10 inches in diameter). In the case of Black Canyon this is the D84 particle size (Elliott and Hammack, 1995). An action-alternative that does not periodically move the D84 fraction results in formation of a pavement.

Elliott and Hammack (their Figure 8A through 8D and Figure 9) show that flows varying from 4,000 to 10,000 cfs are necessary to move cobble sized sediment. Dubinski and Wohl (2007) show that the 10,000 cfs flow reduces channel constriction. They further show that the 6,040 cfs flow mobilizes the size D50 sediment over 50 percent of the alluvial reaches. The 3,000 cfs retains entrainment competency sufficient to mobilize sediment along the low channel margins. An entraining flow of 10,000 cfs occurred every 2 to 3 years before the closure of Blue Mesa's gates.

Duration is defined as follows: if an alternative results in a change in the duration of days of discharge at 10,000 cfs, 6,040 cfs and 3,000 cfs by ± 50 percent, then the duration of impact is defined as being of long-term duration. If an alternative results in a change in the duration of days at discharge 10,000 cfs, 6,040 cfs and 3,000 cfs by less than ± 50 percent, then the duration of impacts is defined as being short-term.

Intensity**:** Intensity is rated in terms of the factors negligible, minor, moderate and major.

1) Negligible intensity – Affect of the proposed operation is essentially not measurable. Negligible intensity is herein defined as a net change in stream power (erosion force) of plus or minus (±) 10 percent.

2) Minor intensity – Affect of the proposed operations is measurable, but the impact possesses little strength. Minor intensity is herein defined as a net change in stream power of ± 10 to 25 percent.

3) Moderate intensity – Affect of an impact is measurable, has significant strength and is of clear difference from the standard for comparison. Moderate intensity is herein defined as a net change in stream power of ± 25 to 40 percent.

4) Major intensity – Affect is measurable, significant and different from the standard for comparison. Major intensity is herein defined as a net change in stream power of ± 40 percent or greater.

Type: An operation that restores sediment transport to the alluvial bottomland at a rate significantly improving upon the No-Action could be beneficial.

IMPACTS TO CHANNEL MAINTENANCE AND SEDIMENT TRANSPORT: This section covers environmental impacts of reoperation alternatives to channel maintenance processes within Black Canyon of the Gunnison National Park.

CONTEXT -- Results for key size classes are summarized in Table 1. Figure 2 shows the relationship between Reach Mobilization and discharge.

Table 1. Reach mobilization for preimpoundment, No-Action and action-alternatives.

	Preimpound-ment Total/ Percentage change from pre-impoundment		**No-Action Total/ Percentage change from pre-impoundment**		**Alternative A Total/ Percentage change from No-Action**		**Alternative B Total/ Percentage change from No-Action**		**Alternative C Total/ Percentage change from No-Action**		**Alternative D Total/ Percentage change from No-Action**	
Percentage of reach mobilized for size D16	72.9	0	40.0	-45	49.3	19	56.2	29	57.4	30	49.8	20
Percentage of reach mobilized for size D50	51.7	0	25.6	-50	29.6	14	34.3	25	35.0	27	30.6	16
Percentage of reach mobilized for size D84	26.1	0	11.8	-56	14.3	17	16.7	29	17.2	31	14.6	19

Operation governed by the No-Action has a negative regional context impact on sediment movement and channel maintenance. Operation governed by the No-Action has lost -56 percent of the preimpoundment capacity to mobilize sediment of the cobble size particles.

In contrast, each action-alternative has a positive local impact on

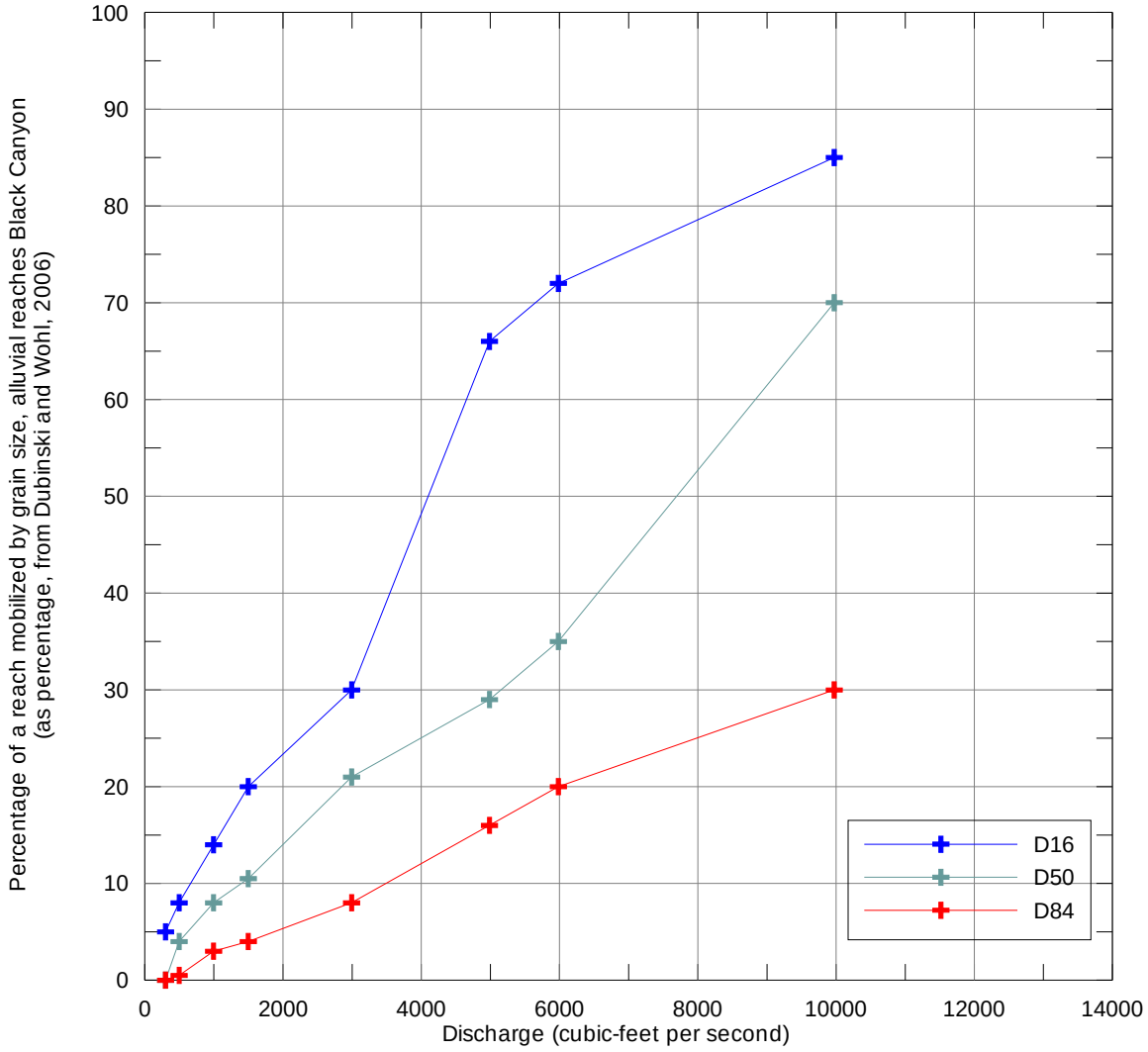

Figure 3. Reach mobilization. Data values scaled from Figure 4 of Dubinski and Wohl. Accuracy is plus or minus 1 percent of the value in their Figure 4.

reach mobilization. Operation governed by action-alternative C is the most effective alternative relative to reach mobilization. Action-alternative A is the least effective.

Operation governed by action-alternative C mobilizes the D84 size particle over about 17 percent of the bottomland (31 more than alternative A). Operation by action alternative A mobilizes the D84 over about 14 percent of the bottomland. The difference relates directly to the average value of the peak flows from the 31 year record used in the alternatives. Mobilization of the D84 by operations governed by action-alternatives B and D are intermediate to C and A. This is true also of the average value of the peak flows.

The context of impacts of reoperation are thus related to the operation rules that result in a decision to release a peak flow. Each of the alternatives can at best offer a positive

local context to channel maintenance in Black Canyon. Operation governed by action-alternative C is the most effective for Black Canyon resources.

DURATION --Dubinski and Wohl (2007) give frequencies for key discharge rates (10,000, 6,040 and 3,000 cfs) as a function of the size-fraction moved. For the preimpoundment, discharge capable of moving the D16 occurred annually at a rate of 37 days per year. Similarly, discharge capable of moving the D50 occurred at a rate of 18 days per year, and the discharge capable of moving the D84 occurred at a rate of 7 days per year.

Table 2 summarizes results. Operations governed by the No-Action and each of the action-alternatives result in a reduction in the number of days of each key flow when compared to the preimpoundment condition (Table 3).

Table 2. Duration and percentage duration for key flows for the preimpoundment and action alternatives.

Discharge (cfs)	Preimpound-ment (Number of days/% days)		No-Action (Number of days/% days)		Alternative A (Number of days/% days)		Alternative B (Number of days/% days)		Alternative C (Number of days/% days)		Alternative D (Number of days/% days)	
10,000	88	0.78	14	0.12	17	0.15	14	0.12	9	0.08	7	0.06
6,040	434	3.8	86	0.76	109	1.0	148	1.3	241	2.1	145	1.3
3,000	1300	11.5	550	4.9	513	4.5	631	5.6	860	7.6	609	5.4

Table 3. Percentage change for key duration flows.

Discharge (cfs)	Preimpound-ment (percentage change in duration of flows)	No-Action (percentage change in duration of flows)	Alternative A (percentage change in duration of flows from NA)	Alternative B (percentage change in duration of flows)	Alternative C (percentage change in duration of flows)	Alternative D (percentage change in duration of flows)
10,000	0	-84	21	0.0	-35	-50
6,040	0	-80	26	72	180	68
3,000	0	-58	-6.7	14	56	11

Operation governed by the No-Action has a negative long-term impact to duration of each of the key flows.

Action-alternative A increases the duration of the 10,000 and 6,040 cfs flows relative to the No-Action. Action-alternative A decreases the fduration of the 3,000 cfs flows. Neither the increase in flow duration (10,000 and 6,040 cfs) nor the decrease (3,000) in flow duration is ± 50 percent, and the change in duration of key flows is short-term.

Action-alternative B has no change in the duration of the 10,000 cfs flows. Action-alternative B increases the duration of the 6,040 by greater than 50 percent and 3,000 cfs by less than 50 percent. The change in the duration of the 10,000 cfs flow is short-term. The change in duration of the 6,040 cfs flows is long-term, while change in the duration of 3,000 cfs flows is short-term.

Action-alternative C decreases the duration of the 10,000 cfs flows by 35 percent. Action-alternative C increases the duration of the 6,040 by 180 percent and 3,000 cfs by 56 percent. The decrease in the duration of the 10,000 cfs flows is short-term. The increase in the 6,040 and 3,000 cfs flows is long-term.

Action-alternative D decreases the duration of the 10,000 cfs flows by 50 percent. Action-alternative D increases the duration of the 6,040 by greater than 180 percent and 3,000 cfs by 56 percent. The increase in the 6,040 cfs flows is long-term, however the overall result is assessed short-term owing to the negative long-term duration of the 10,000 cfs flows.

Owing to the importance of the 6,040 cfs duration flows to sediment mobilization of the D50 particle compared to the importance of the 3,000 cfs duration flows, operations under action-alternatives B and C are assessed to be of positive, long-term duration.

INTENSITY -- Intensity is a comparison of whether the flow regimes governed by the No Action and each action-alternative A through D can result in significantly different movement of sediment. The metric employed is stream power.

Stream power is a measure of the force directed against a unit length of channel per time. The correspondence is straight-forward, the greater power applied the more sediment that is potentially mobilized. The number presented is the sum of the power resulting from the operational peak flows over the 31 years.

Stream power is functionally related to entrainment of sediment and the metric Reach Mobilization. Comparison locations are for study reaches below the Warner Point and at the mouth of Red Rock Canyon. Utilization of the metric stream power removes from comparison the effects of geomorphic features, thus presently a clearer picture of the differences in intensity of the action-alternatives.

Operation governed by the No-Action reduces the eroding force of the river at Warner Point and at Red Rock Canyon by greater than 50 percent. This is a major-intensity impact to eroding force.

Operations governed by the action-alternatives A through D increases the eroding force of the river through the application of peak flows. Operations governed by action-alternatives A and D result in a minor intensity increase in eroding force.

Operations governed by the action-alternatives B and C result in a moderate-intensity increase in eroding force.

Table 4. Total force and change in total force for the preimpoundment, No-Action and action alternatives. Units are pounds/sec.

Location	Preimpound-ment Total/ Percentage change from pre-impoundment		No-Action Total/ Percentage change from pre-impoundment		Alt A Total/ Percentage change from No-Action		Alt B Total/ Percentage change from No-Action		Alt C Total/ Percentage change from No-Action		Alt D Total/ Percentage change from No-Action	
Warner Point	54,559	0	26,204	-52	31,406	20	36,887	41	37,595	43	32,470	24
Red Rock[1]	341,809	0	133,703	-61	160,506	20	187,506	40	194,293	45	165,832	24

[1]A greater eroding force is applied at the Red Rock reach as opposed to the Warner Point Reach because the river is falling faster. Said differently, the energy gradient is stronger.

TYPE -- Type is a qualitative assessment indicator composed of the quantitative results of the analysis factors.

The No-Action alternative by definition does not benefit sediment transport in Black Canyon. It is of negative regional context and would have a negative long-term duration impact. The changes wrought by operations under the No-Action are major in intensity. The type of impact is adverse.

Alternative A offers a minor benefit to sediment transport in Black Canyon as compared to the No-Action. Impacts are local in context and of short-term duration. Increased sediment mobilization is minor in intensity. Probable time intervals between peak flows for operations partly governed by the April-July runoff forecast are long, possibly 18 years. An operation offering minor improvement in scour on a short-interval time scale is deemed of type adverse.

Alternative B offers a moderate benefit to sediment transport in Black Canyon as compared to the No-Action. Impacts are local in context, but of long -term duration impact. Sediment mobilization is moderate in intensity. Probable maximum time intervals between 10,000 cfs peak flows for operations partly governed by the April-July runoff forecast are long, possibly 18 years. Probable maximum time intervals between key 6,040 cfs flows are reasonably close to preimpoundment maximums which is beneficial.

The local context is reason for concern. However, the long-term duration and moderate intensity scour is deemed beneficial.

Alternative C offers a moderate benefit to sediment transport in Black Canyon as compared to the No-Action. Impacts are local in context, but of long -term duration impact. Scour is moderate in intensity. Probable maximum time intervals between 10,000 cfs peak flows for operations partly governed by the April-July runoff forecast are long, possibly 18 years. Probable maximum time intervals between key 6,040 cfs flows are closer to pre-impoundment maximums than for alternative B.

The local context is reason for concern. Operations governed by action-alternative C offer a major improvement in to transport of the D50 sediment. An operation offering overall moderate intensity scour – coupled with the major intensity mobilization of the D50 particle size for extended reaches is deemed beneficial.

Alternative D offers a minor benefit to sediment transport in Black Canyon as compared to the No-Action. Impacts are local in context and of short-term duration impact. Improvements would be minor in intensity. Probable time intervals between peak flows for operations partly governed by the April-July runoff forecast are long, possibly 18 years. An operation offering minor benefits on a long-interval time scale are deemed of type adverse.

The results from analysis of the impacts of alternatives are summarized in Table 5.

Table 5. Summary of results.

Alternative	Context	Duration	Intensity	Type
No-action	Regional	Long-term	Negligible	Adverse
Alt A	Local	Short-term	Minor	Adverse
Alt B	Local	Short-term	Moderate	Beneficial
Alt C	Local	Short-term	Moderate	Beneficial
Alt D	Local	Short-term	Minor	Adverse

DISCUSSION -- According to Dubinski and Wohl flows equal to or exceeding 10,000 cfs do not have to occur every year, but need to occur “every few years”. Prior to operations at Aspinall, flows of 10,000 cfs occurred every 2 to 4 years (probability of occurrence of ½ to ¼ or approximately 1/3).

The Blue Mesa inflow with a return interval of 3 years is approximately 775,000 AF. Historically April – July flows from the watersheds above Blue Mesa produced a peak of about 10,000 cfs in Black Canyon for the runoff condition of 750,000 to 800,000 AF. The probability of going 5 consecutive years without an inflow of 775,000 is small, 13/100. The likelihood of going 10 years without an inflow of 775,000 is very small, 1/100. The erosive power of the 10,000 cfs flow coupled with the low probability of going 5 years without it (10,000 cfs flow) historically controlled the sediment mobilization in Black Canyon, and it had since the close of the ice ages.

Neither the No-Action nor the action alternatives produce a 10,000 cfs peak at this return interval. The 10,000 cfs key duration flows in the No-Action and the action alternatives result from forecast error; the 10,000 flows result when Blue Mesa inflow is “underforecasted” by an amount approaching 170,000 AF (Figure 4).

Regulated peak flows through Black Canyon are a function of the forecasted inflow to Blue Mesa Reservoir. Observed unregulated inflow is a random variable. The May 1 forecasted April-July inflow to Blue Mesa is a variable conditioned on observations of snow pack water content and past runoff (8 readings at 6 stations). Figure 5 shows the distribution of the observed unregulated inflows to Blue Mesa. Plotted with the distribution of unregulated flows is the “distribution” of the forecasted inflows. The graphs and return intervals are

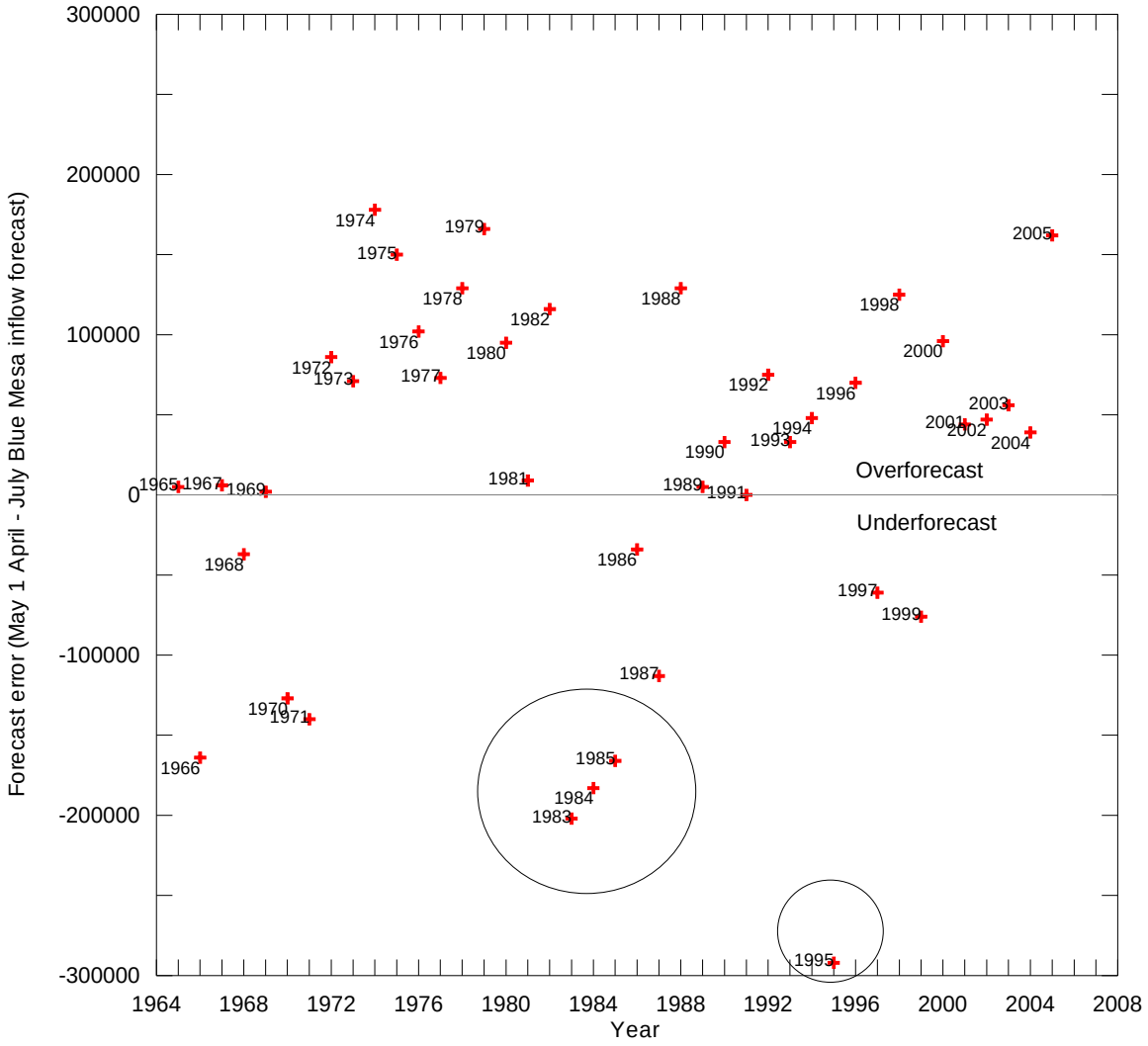

Figure 4. Relationship between forecast and peak flows through Black Canyon.

similar allowing a comparison of expected return intervals for key duration flows as produced by the operations model.

A return interval for the 10,000 cfs flows was estimated by fitting the 31 year record of model-derived peak flows to the Pearson LogIII distribution. Corresponding return intervals were matched together, for example the 5 year return inflow is 932,695 AF. The probable 1 in 5 year peak flow for the No Action alternative is 5,766 cfs. The important result is that the return interval for the 10,000 cfs peak for the No-Action is approximately 12 years. The return interval for 10,000 cfs duration flow for each of the action alternatives is about 10 years.

Table 6. Pearson Log III derived Blue Mesa unregulated inflow, and model-derived peak flows for the included return intervals.

Return Interval (years)	Probability of peak flow	Observed April – July to Blue Mesa inflow	No-Action	Alt A	Alt B	Alt C	Alt D
1.05	95.2	253,273	534	733	1,033	1,046	679
1.1	90.1	324,780	762	1,055	1,559	1,586	1,005
1.25	80	426,572	1,169	1,616	2,431	2,481	1,582
2	50	662,908	2,615	3,473	4,894	5,005	3,542
5	20	932,695	5,766	7,015	8,206	8,373	7,346
10	10	1,075,638	8,663	9,886	10,081	10,252	10,435
25	4	1,221,997	13,313	14,066	12,018	12,176	14,853
50	2	1,309,834	17,529	17,373	13,179	13,316	18,437
100	1	1,384,029	22,403	20,943	14,133	14,245	22,207
200	½	1,447,177	28,033	24,733	14,930	15.015	26,190

Operations for each action-alternative reduce the duration of the 10,000 cfs. Operations also effectively reduce the probability that in any year operations will produce a 10,000 cfs flow. Prior to regulation, the probability of going 5 years between flows of 10,000 was small, 13/100. For each of the action alternatives, there is the same probability (13/100) of going 28 years without a flow of 10,000 cfs. This is too long.

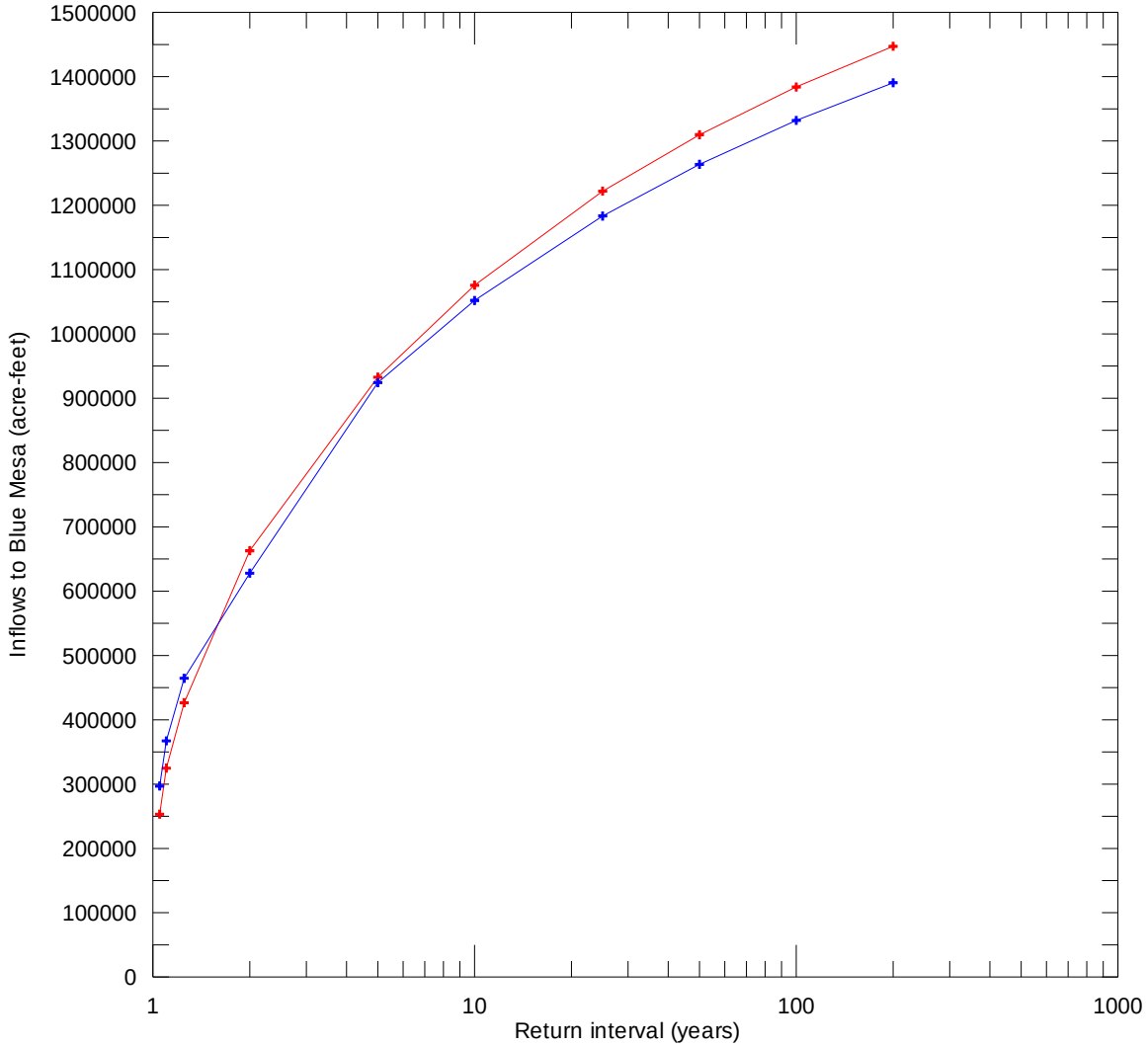

Figure 5. Return intervals for observed unregulated inflow to Blue Mesa (red) and for forecasted unregulated inflow to Blue Mesa (blue)

SUMMARY: Action-alternatives B and C are the most effective for channel maintenance of the four action alternatives. Each has a moderate intensity scour, resulting primarily from the effect of the 6,000 cfs class of peak flows. This is beneficial for channel maintenance and sediment mobilization and partly explains the beneficial rating. Over time, however, owing to the lack of the 10,000 cfs class flows it will become ever more difficult to move the larger sediment size, the D84, and operations governed by action alternatives B and C will become ineffective. Failure to move the D84 impacts the entrainment of the smaller sediment within the interstices of the cobbles. The net result is continued storage of sediment within the alluvial channel. Operations governing the No-Action and action alternatives A utilize under-forecasted runoff values to produce peak outflows.

NPS ANALYSIS OF IMPACTS OF ASPINALL REOPERTIONS ON RIPARAIN RESOURCES

BACKGROUND: A measure of the ecological change in Black Canyon resulting from 40 years of operations at Aspinall is establishment of vegetation where it would not have naturally occurred. Regulation by Aspinall has resulted in the alluvial bottomland being colonized with woody plants, and the alluvial bottomland being vegetated with arid species at the expense of moderately wet species. These changes represent fundamental changes in the riverine ecology.

Two metrics are employed in this evaluation. The metric utilized for determination of impacts of reoperation on the establishment of woody vegetation is percentage of bottomland sheared under each alternative. The functional relationship is developed by Friedman and Auble (1999).

The metric utilized for determination of impacts of reoperation on herbaceous plant community composition is percentage of bottomland vegetation classed as xeric (dry site), mesic (moderately wet site), hydric (very wet to saturated), and aquatic (continuously saturated). The functional relationship between discharge and community composition is developed from Auble and others (1994).

The metrics used are interrelated measures each dependent on the magnitude and duration of high spring-season flows.

NEPA DEFINITIONS: RIPARIAN RESOURCES ANALYSIS, WOODY VEGETATION

Context is herein defined as a function of the shear of bottomland vegetation. An operation that results in changes in the percentage of bottomland sheared by less than ±50 percent is defined as having a local context. An operation that results in changes in the percentage of bottomland woody vegetation removed by greater than ± 50 percent is defined as having a regional context (see Table 7 for percentage of vegetation removed).

Duration is herein defined as a function of the probability of 15 years passing without a peak flow of 10,000 cfs. The selection of the 15 year time period is motivated by Friedman and Auble (1999, p. 473) who stated “low-flow periods longer than 10 – 15 years may result in irreversible streamward encroachment of woody vegetation”. Prior to regulation, a flow of 10,000 cfs was expected at a frequency of about 1 in 3 years. The probability of going 15 years without a 10,000 cfs flow was vanishing small, 2 in 1000.

The No-Action alternative has a probability of 0.27 of 15 years passing without a flow of 10,000 cfs. Each action-alternative, A - D has a lower probability, about 0.2, of 15 years passing without a flow of 10,000 cfs.

Table 7. Percentage of vegetation removed by shear, 85-day inundation and the change in percentage vegetation removed by shear

Percentage vegetation removed	Preimpound-ment	No-Action	Alternative A	Alternative B	Alternative C	Alternative D
Total	33	21	23	25	26	23
Shear	30	11	14	18	18	15
Inundation	3	10	9	7	8	8
Percent change by shearing (total)	0	-63	27	39	39	36

Intensity: Intensity is defined in terms of total change in percentage of the bottomland cleared (Table 8, column 4). Total change (as a percentage) is computed as the mean of the annual percentages of bottomland cleared.

1) Negligible intensity is herein defined as a net change in the total bottomland cleared of vegetation by ± 10 percent.

2) Minor intensity is herein defined as a net change in the total bottomland cleared of vegetation in the range ± 10 to 25 percent.

3) Moderate intensity is herein defined as a net change in the total bottomland cleared of vegetation in the range in the range ± 25 to 40 percent.

4) Major intensity is herein defined as a net change a net change in the total bottomland cleared of vegetation by ± 40 percent or greater.

Type: An operation which clears the canyon bottomland to a degree significantly improving upon the No-Action could be beneficial.

ANALYSIS OF IMPACTS: Table 8 summarizes impacts to riparian resources establishment of woody vegetation.

Table 8. Summary of impacts: vegetation removal by shearing

Alternative	Context	Duration	Intensity	Type
No-Action	Regional	Long-term	Negligible	Adverse
Alternative A	Local	Short-term	Moderate	Adverse
Alternative B	Local	Short-term	Moderate	Adverse
Alternative C	Local	Short-term	Moderate	Advere
Alternative D	Local	Short-term	Moderate	Adverse

Preimpoundment condition is characterized of woody vegetation control predominantly by the mechanism of shear, which mechanically removed encroaching vegetation. Inundation as a means of woody vegetation control was negligible. Regulation results in loss of major loss of woody vegetation shearing.

The No-Action alternative by definition does not prevent establishment of woody vegetation in Black Canyon. The No-Action is regional context and would have a

negative long-term duration impact. The intensity of change is major (relative to the preimpoundment) and the impact type is adverse.

Action-alternative A offers an increase in total percentage of bottomland shear in Black Canyon compared to the No-Action. Impacts are local in context and of short-term duration. The intensity of the impact is moderate. An action-alternative offering short-term, moderate improvement in shear over local areas is type adverse.

Action-alternative B offers an increase in total percentage of bottomland shear in Black Canyon. Impacts are local in context and of short-term duration. The intensity of the impact is moderate. An action-alternative offering short-term, moderate improvement in shear over local areas, and for short-term duration is type adverse.

Action-alternative C offers a moderate increase in total percentage of bottomland shear. Impacts are local in context and of short-term duration. The intensity of the impact is moderate. An action-alternative offering improvement in shear over local areas, and for short-term duration is type adverse.

Action-alternative D offers a moderate increase in total percentage of bottomland shear. Impacts are local in context and of short-term duration. The intensity of the impact is moderate. An action-alternative offering improvement in shear over local areas, and for short-term duration is type adverse.

NEPA DEFINITIONS: RIPARIAN RESOURCES ANALYSIS, COMMUNITY COMPOSITION

Context is herein defined as a function of the percentage change in bottomland community composition of herbaceous vegetation. The principal change effected by Aspinall operation is in the percentage of bottomland in xeric (dry-site) and mesic (moderately wet site) plant communities. A local context change is herein defined in a percentage change of less than ± 50 in the occurrence of mesic plants. A regional context is defined as greater that ± 50 percent change in the occurrence of mesic plants.

Duration is defined a function of the frequency of inundation by 6,040 cfs flows and ensuing plant community type (see Figure 6). Occurrence of a xeric community implies that the bottomland is inundated at a frequency less than 0.01 (between 3 and 4 days). Occurrence of a mesic plant community implies that the bottomland is inundated for at least 3 days and for no more than approximately 75 days during the growing season. Occurrence of a hydric community implies inundation of at least 18 days and a maximum of 180 days. The metric adopted herein is change in frequency percentage of time the Canyon bottomland is inundated by flows at or above 6,000 cfs. If the percentage change is ± 50 percent of less, then the duration is short-term. If the percentage change is greater than ± 50 percent, then the duration is long-term.

Intensity is defined in terms of total change in percentage of bottomland in community type mesic.

1) Negligible intensity – is herein defined as a net change in the total bottomland populated with mesic community by ± 10 percent.

2) Minor intensity is herein defined as a net change in the total bottomland populated with mesic community in the range ± 10 to 25 percent.

3) Moderate intensity is herein defined as a net change in the total bottomland populated with mesic community in the range in the range ± 25 to 40 percent.

4) Major intensity is herein defined as a net change a net change in the total bottomland populated with mesic community by ± 40 percent or greater.

Table 9. Herbaceous plant community composition and change in community composition in Black Canyon for the preimpoundment and each proposed alternative

Percentage vegetation as community type	**Preimpoundment**	**No-Action**	**Alternative A**	**Alternative B**	**Alternative C**	**Alternative D**
Xeric	3	9	6	6	4	6
Percent change in xeric community	0	200	-33	-33	-55	-33
Mesic	69	57	60	61	67	61
Percent change in percentage mesic community	0	-17	5	7	18	7

Table 10. Flow duration and change in flow duration in Black Canyon for the preimpoundment and each proposed alternative

Alternative	**Preimound-ment**		**No-Action**		**Alternative A**		**Alternative B**		**Alternative C**		**Alternative D**	
Days > 10,000 cfs	123	0	14	-88	17	21	14	0	9	-36	7	-50
Days > 6,040 cfs[1]	484	0	86	-84	109	26.7	148	72.1	241	180	145	68.6

[1] The duration of 6,040 cfs flowsprior to regulation was approximately 4 percent (16 days per year)

ANALYSIS OF IMPACTS: Figure 6 presents the dynamics of community composition as a function of inundation duration. Flows of 6,000 cfs are the flows that inundate the canyon bottomland and the inundation frequency plotted is the frequency of specifically the 6,040 cfs flows. For example, a frequency of inundation of 0.05 corresponds to an average annual inundation of 18 days. Table 9 presents the changes in plant ecological community composition. Table 10 presents the change in duration of 10,000 and 6,040 cfs flows. Table 11 summarizes the findings.

Operation governed by the No-Action alternative has had a regional scale, long-term and major intensity impact to Black Canyon plant community resources; the principal impact is encroachment of xeric plant communities at the expense of mesic communities and an encroachment riverward of the mesic community.

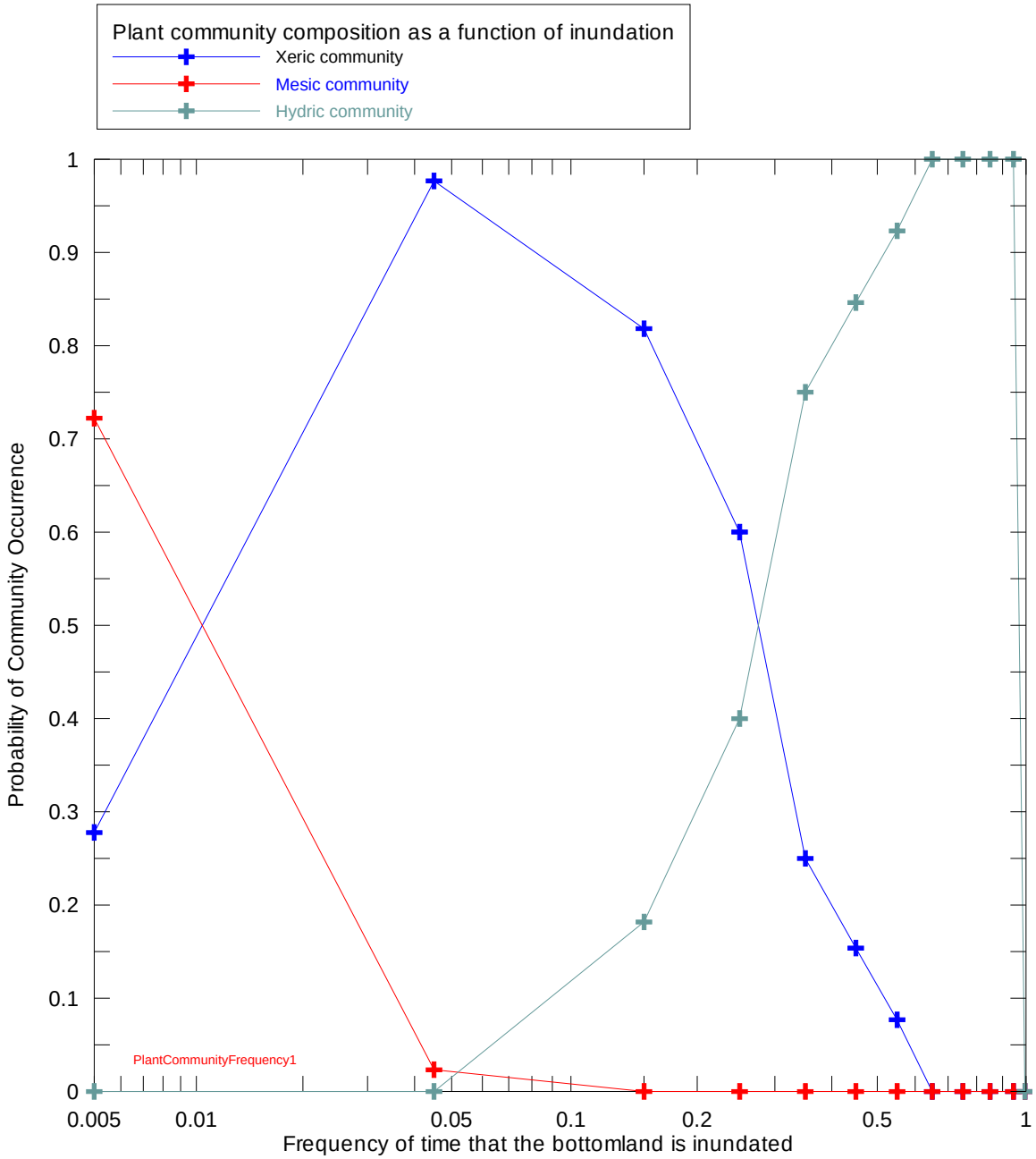

Figure 6. Probability of herbaceous community type as a function of inundation frequency (from of Auble and others, 1994).

Operation governed by action-alternative A can be expected to have local scale, short-term decrease in bottomland vegetated by xeric species. Intensity of decrease is moderate. Operation A will decrease the percentage of bottomland vegetated by xeric species. The improvement in mesic communities is negligible. The principal impact is loss of xeric communities without a consequent gain in hydric communities.

Operation governed by action-alternative B can be expected to have local scale, short-term decrease in bottomland vegetated by xeric species. Intensity of decrease is

moderate. Action-alternative B will decrease the percentage of bottomland vegetated by xeric species. The improvement in mesic communities is negligible. The principal impact is loss of xeric communities without a consequent gain in hydric communities.

Operation governed by action-alternative C can be expected to have regional scale, short-term decrease in bottomland vegetated by xeric species. Intensity of decrease (in xeric) is major and the increase in mesic community is moderate. This is also a minor increase in communities classed as hydric. This last point makes the type beneficial. It owes to the increase in duration of 6,040 cfs flows to about 8 days per year.

Operation governed by action-alternative D can be expected to have local scale, short-term decrease in bottomland vegetated by xeric species. Intensity of decrease is moderate. Operation A will decrease the percentage of bottomland vegetated by xeric species. The improvement in mesic communities is negligible. The principal impact is loss of xeric communities without a consequent gain in hydric communities.

Table 11. Summary of findings for impacts to herbaceous plant community composition

Alternative	Context	Duration	Intensity	Type
No-Action	Regional	Long-term	Major	Adverse
Alternative A	Local	Short-term	Negligible	Adverse
Alternative B	Local	Short-term	Negligible	Adverse
Alternative C	Regional	Long-term	Major	Beneficial
Alternative D	Local	Short-term	Negligible	Adverse

SUMMARY: The proposed action-alternatives lack sufficient flows at or above 10,000 cfs to prevent colonization of woody vegetation. The 10,000 cfs flows are the flows with sufficient shear force to accomplish removal of woody plants by mechanical action.

Operation governed by the No-Action alternative and action-alternatives A and D lack sufficient flows at 6,000 cfs to prevent continued drying of the alluvial bottomland. This is expected to happen owing to encroachment of xeric community onto the mesic community and the mesic onto the hydric community.

Operations governed by action-alternatives B or C can be expected to slow the encroachment of the xeric onto the mesic community and to slow the encroachment of the mesic onto the hydric community. This results from the greater frequency of inundation of the alluvial bottomland. As stated previously, these alternatives lack the 10,000 cfs flows necessary to prevent colonization of the alluvial bottomland by woody vegetation.

The shearing flows and sediment remobilization flows are essentially the same and the results of the work (done by the 10,000 cfs flows) interrelated. When the cobble-size sediment is mobilized the woody and herbaceous vegetation is also sheared away. Without the shearing flows the practical result of the inundation flows is to irrigate the bottomland facilitating growth of invasive riparian plants, for example reed canary grass. A negative impact to action alternatives B and C is the possible loss of native plants communities that were in balance with the frequent shearing flows.

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