CHAPTER II

Description of Alternatives

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This chapter presents the process used to formulate alternatives, the alternatives considered in detail, the alternatives eliminated from detailed study, and a summary comparison of the alternatives and their impacts.

PROCESS USED TO FORMULATE ALTERNATIVES

Alternatives for the draft Glen Canyon Dam Environmental Impact Statement (EIS) were formulated through a systematic process using public input, technical information, interdisciplinary discussions, and professional judgment. The process began with consideration of Glen Canyon Environmental Studies (GCES) Phase I recommendations and comments from the 1990 public scoping activities.

In July 1990, representatives from cooperating agencies and various interest groups participated in a "brainstorming" workshop to fully consider all concepts and suggestions in formulating alternatives (Bureau of Reclamation, 1990a).

The interdisciplinary, interagency EIS team then formulated 10 preliminary alternatives divided into 3 descriptive categories: fluctuating flows, steady flows, and flows mimicking predam conditions. Some of these preliminary alternatives included various structural elements that would provide warmer release temperatures in the summer, bypass sediment around the dam, or reregulate releases to provide steady flows downstream.

The team presented these alternatives to the cooperating agencies and, following their approval, presented them to the public in a newsletter (Bureau of Reclamation, 1991a) and three public meetings held in Salt Lake City, Utah, and Flagstaff and Phoenix, Arizona, during April 1991. These original alternatives ranged from providing high, warm, and sediment-laden flows each spring (with relatively low flows the remainder of the year) to providing steady, cool, and clear flows throughout the year. They ranged from steady flows throughout the day to high daily fluctuations.

The public was asked to comment on the range of preliminary alternatives as part of the EIS scoping process (Bureau of Reclamation, 1991b). The predominant public comment was the need for "operation only" alternatives and/or separate analysis of operational and nonoperational (structural) measures. Other comments most frequently voiced were:

- An alternative should be developed that maximizes benefits to endangered species and recreation.
- Alternative dam operations should be considered to reduce the frequency of floods and daily fluctuations.
- The reregulation dam is not a reasonable alternative and should not be considered.
- Not only is a reregulation dam a viable alternative, but a powerplant should be added to help pay the cost.
- The historic or natural flow patterns should serve as the baseline (No Action Alternative) for comparison of alternatives.
- None of the alternatives should include structural elements.
- The environmental, social, and economic effects of reduced electrical generation should be evaluated in steady flow alternatives.
- A lower fluctuating flow alternative should be formulated with a maximum of 20,000 cubic feet per second (cfs) and a minimum of 8,000 cfs. Ramp rates should be 1,000 cfs per hour up and 500 cfs per hour down, with no more than 3,000 cfs change from day to day. (Many flow regime variations were received.)

Using this additional input, professional judgment, and analysis of interim flows, the EIS team reviewed and revised the preliminary alternatives. Seven alternatives were then identified for detailed analysis, and others were considered and eliminated from detailed study. Later, to present a full range of reasonable operations, two more alternatives were formulated. As a result of comments on both the draft EIS and draft biological opinion and discussions with the U.S. Fish and Wildlife Service (FWS), the preferred alternative described in the draft EIS was revised with the broad support of the cooperating agencies (see Modified Low Fluctuating Flow Alternative later in this chapter). The EIS team and cooperating agencies attempted to balance benefits to all resources (physical, biological, cultural, and consumable) in identifying a preferred alternative. Figure II-1 summarizes the alternatives and their descriptions.

ALTERNATIVES CONSIDERED IN DETAIL

The nine alternatives considered in detail are described below, beginning with the No Action Alternative (historic operations) to provide a baseline for comparison. Table II-1 presents a summary of operating limits under the nine alternatives identified for detailed analysis.

The eight action alternatives were designed to provide a broad spectrum of options. One alternative would allow unrestricted fluctuations (within the physical constraints of the powerplant) in flow to maximize the value of power, four would impose varying restrictions on fluctuations, and three others would provide steady flows on a monthly, seasonal, or annual basis. The names of the alternatives reflect the operational regimes they represent.

Table II-2 shows the frequency of minimum and maximum releases and daily fluctuations under all Glen Canyon Dam EIS alternatives.

All of the restricted fluctuating flow and steady flow alternatives include the following elements designed to provide additional resource protection or enhancement. These common elements are discussed in detail later in this chapter.

- Adaptive management (including ongoing monitoring and research)
- Monitoring and protecting cultural resources
- Flood frequency reduction measures
- Beach/habitat-building flows
- New population of humpback chub
- Further study of selective withdrawal
- Emergency exception criteria

Table II-2.–Percent of days that minimum and maximum releases and daily fluctuations occur under the alternatives

Alternative	Minimum releases <8,000 cfs (percent of days)	Maximum releases >20,000 cfs (percent of days)	Daily fluctuations >6,000 cfs (percent of days)
No action	90	72	97
Maximum powerplant capacity	90	73	97
High fluctuating flow	79	65	96
Moderate fluctuating flow	41	23	89
Modified low fluctuating flow	29	19	54
Interim low fluctuating flow	29	19	54
Existing monthly volume steady flow	<1	[1]7 to 18	0
Seasonally adjusted steady flow	<1	[1]5 to 27	0
Year-round steady flow	<1	[1]8 to 12	0

[1] Depending on season.

Alternative	Description
STUDIED IN DETAIL:	
Unrestricted Fluctuating Flows	
No Action	Maintain fluctuating releases and provide a baseline for impact comparison.
Maximum Powerplant Capacity	Permit use of full powerplant capacity.
Restricted Fluctuating Flows	
High	Slightly reduce daily fluctuations from historic no action levels.
Moderate	Moderately reduce daily fluctuations from historic no action levels; includes habitat maintenance flows.
Modified Low (*Preferred Alternative*)	Substantially reduce daily fluctuations from historic no action levels; includes habitat maintenance flows.
Interim Low	Substantially reduce daily fluctuations from historic no action levels; same as interim operations.
Steady Flows	
Existing Monthly Volume	Provide steady flows that use historic monthly release strategies.
Seasonally Adjusted	Provide steady flows on a seasonal or monthly basis; includes habitat maintenance flows.
Year-Round	Provide steady flows throughout the year.
CONSIDERED BUT ELIMINATED:	
Mimic Predam Flows	
Run-of-the-River Historic Pattern	Provide flow conditions similar to predam conditions: high, warm spring floods and sediment augmentation.
Reregulated Flow	Maximize fluctuations from the dam to Lees Ferry, with a reregulation dam providing near-steady flows downstream.

Figure II-1.—Glen Canyon Dam EIS alternatives.

Table II-1.–Operating limits of alternatives identified for detailed analysis

	Unrestricted Fluctuating Flows		Restricted Fluctuating Flows				Steady Flows		
	No Action	**Maximum Powerplant Capacity**	**High**	**Moderate**	**Modified Low**	**Interim Low**	**Existing Monthly Volume**	**Seasonally Adjusted**	**Year-Round**
Minimum releases (cfs)[1]	1,000 Labor Day–Easter [2]3,000 Easter–Labor Day	1,000 Labor Day–Easter [2]3,000 Easter–Labor Day	3,000 5,000 8,000 depending on monthly volume, firm load, and market conditions	5,000	8,000 between 7 a.m. and 7 p.m. 5,000 at night	8,000 between 7 a.m. and 7 p.m. 5,000 at night	8,000	[3]8,000 Oct–Nov 8,500 Dec 11,000 Jan–Mar 12,500 Apr 18,000 May–Jun 12,500 Jul 9,000 Aug–Sep	Yearly volume prorated[4]
Maximum releases (cfs)[5]	31,500	33,200	31,500	31,500 (may be exceeded during habitat maintenance flows)	25,000 (exceeded during habitat maintenance flows)	20,000	Monthly volumes prorated	18,000 (exceeded during habitat maintenance flows)	Yearly volume prorated[4]
Allowable daily flow fluctuations (cfs/24 hours)	30,500 Labor Day–Easter 28,500 Easter–Labor Day	32,200 Labor Day–Easter 30,200 Easter–Labor Day	15,000 to 22,000	±45% of mean flow for the month not to exceed ±6,000	[6]5,000 6,000 or 8,000	[6]5,000 6,000 or 8,000	[7]±1,000	[7]±1,000	[7]±1,000
Ramp rates (cfs/hour)	Unrestricted	Unrestricted	Unrestricted up 5,000 or 4,000 down	4,000 up 2,500 down	4,000 up 1,500 down	2,500 up 1,500 down	2,000 cfs/day between months	2,000 cfs/day between months	2,000 cfs/day between months
Common elements	None	None	Adaptive management (including long-term monitoring and research) Monitoring and protecting cultural resources Flood frequency reduction measures Beach/habitat-building flows New population of humpback chub Further study of selective withdrawal Emergency exception criteria						

1 In high volume release months, the allowable daily change would require higher minimum flows (cfs).
2 Releases each weekday during recreation season (Easter to Labor Day) would average not less than 8,000 cfs for the period from 8 a.m. to midnight.
3 Based on an 8.23-million-acre-foot (maf) year; in higher release years, additional water would be added equally to each month, subject to an 18,000-cfs maximum.
4 For an 8.23-maf year, steady flow would be about 11,400 cfs.
5 Maximums represent normal or routine limits and may necessarily be exceeded during high water years.
6 Daily fluctuation limit of 5,000 cfs for monthly release volumes less than 600,000 acre-feet; 6,000 cfs for monthly release volumes of 600,000 to 800,000 acre-feet; and 8,000 cfs for monthly volumes over 800,000 acre-feet.
7 Adjustments would allow for small power system load changes.

Unrestricted Fluctuating Flows

No Action Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
1,000 Labor Day to Easter	31,500	30,500 Labor Day to Easter	Unrestricted
3,000 Easter to Labor Day		28,500 Easter to Labor Day	

The No Action Alternative (historic operations) is presented first to provide an understanding of baseline conditions and operations at Glen Canyon Dam. This alternative provides the basis for impact comparison.

Within the overall Colorado River Storage Project purpose, the objective of the No Action Alternative is to produce the greatest amount of firm capacity and energy practicable while adhering to the releases required under the "Law of the River." Under no action, Glen Canyon Dam operations would be the same as they were from 1963—when the dam was placed in operation—until the research flows began in June 1990. This alternative would continue operations established under the *Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs* (Long-Range Operating Criteria) (see attachment 3) as well as daily fluctuating releases. The maximum allowable discharge during fluctuations is 31,500 cfs. Fluctuating releases occur when the dam is being operated to follow power system load changes, to produce peaking power, to regulate the power system, or to respond to power system emergencies.

Annual Release Volume. The principal factors considered in determining annual release volumes are:

- Releasing a minimum of 8.23 million acre-feet (maf) (specified in the Long-Range Operating Criteria)
- Maintaining conservation storage
- Avoiding anticipated spills
- Balancing storage between Lakes Powell and Mead

Annual release volume is based on inflow and remaining space in the two reservoirs. Annual release volumes vary greatly, but all adhere to the Long-Range Operating Criteria objectives of an 8.23-maf minimum annual release and equalized storage between Lake Powell and Lake Mead. Annual releases greater than the minimum are permitted to avoid anticipated spills and to equalize storage.

From 1966 to 1989, annual releases ranged from 8.23 maf to 20.4 maf (1984). The minimum release has occurred in about half the years since the dam was closed in 1963. Historic predam and postdam annual flows at Lees Ferry are shown in figure II-2(a). This figure shows the reduced variation in annual flows after closure of the dam.

Monthly Release Volume. Under the No Action Alternative, the volume of water released from Lake Powell each month depends on forecasted inflow, existing storage levels, monthly storage targets, and annual release requirements. Demands for electrical energy, fish and wildlife needs, and recreation needs also are considered and accommodated as long as the risk of spilling and storage equalization between Lakes Powell and Mead are not affected.

Power demand is highest during winter and summer months, and recreation needs are highest during the summer. Therefore, higher volume releases are scheduled during these months whenever possible to benefit these uses.

Spills are excess annual releases that cannot be used for project purposes; they usually are the result of inflow forecast changes. Floodflows are the spills of principal concern. Floodflows are releases greater than the designed powerplant capacity that are discharged through the river outlet works and spillways.

Each month during the inflow forecast season (January to July), the volume of water to be released for the rest of the year is recomputed based on updated streamflow forecast information. Scheduled releases for the remaining months are adjusted to avoid anticipated spills and maintain conservation storage in accordance with the Long-Range Operating Criteria.

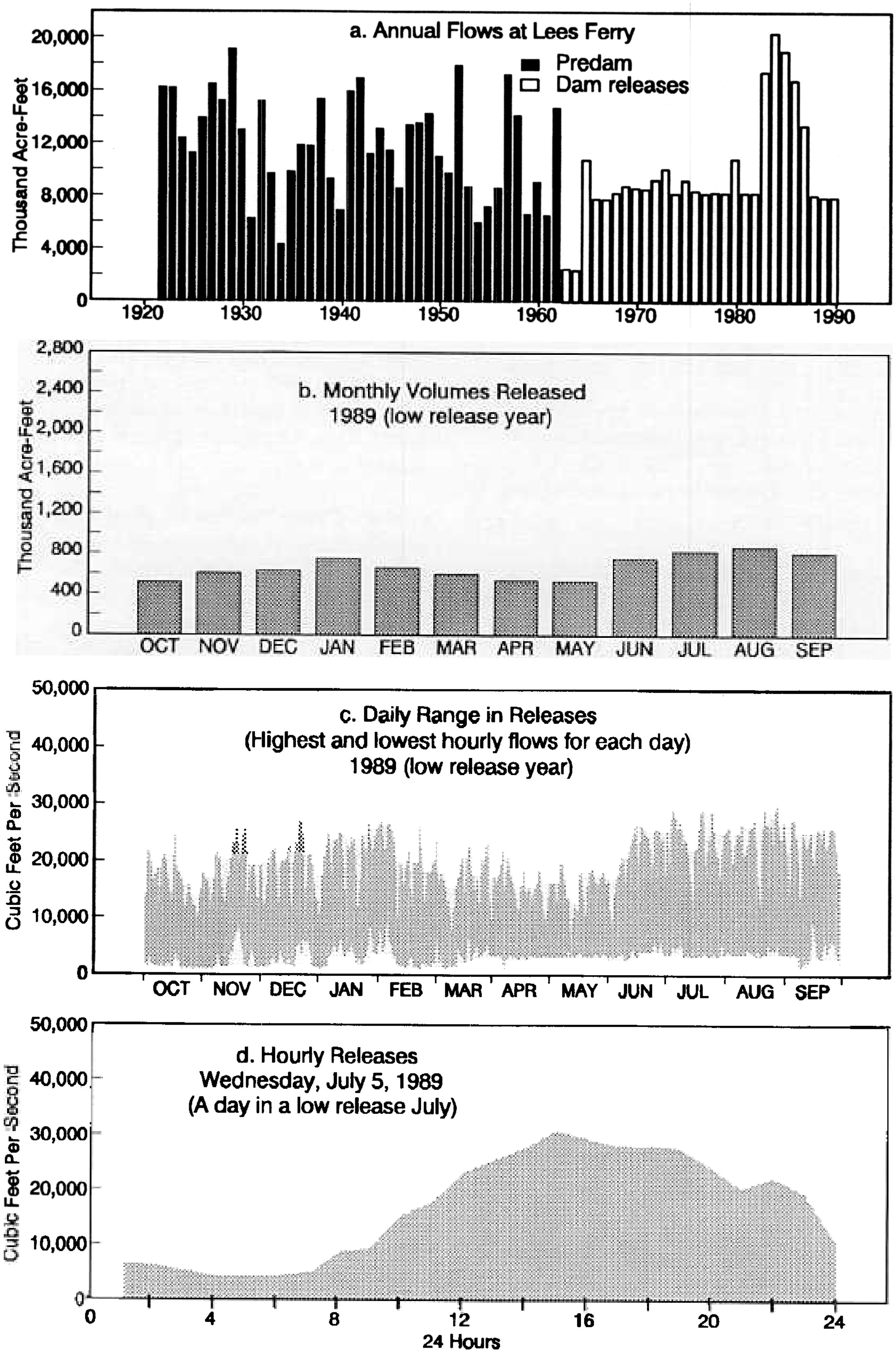


Figure II-2.—Historic water releases from Glen Canyon Dam.

Figure II-2(b) shows historic monthly release volumes for a low (minimum) release year, which occurs the most frequently. Figure II-3 presents a comparison of historic monthly releases among example low, moderate, and high release years.

Under high storage conditions, fall and early winter releases are designed to meet the January 1 storage target (22.6 maf). Under lower storage conditions, releases are scheduled at a minimum of about 550,000 acre-feet per month. January through July releases are scheduled to create space in the reservoir so that the forecasted runoff will not produce spills but will fill the reservoir in July. July through September releases are used to meet the minimum annual release requirement and reach the January 1 target of 22.6 maf.

Floodflow Avoidance Measures. Methods for providing protection against flood releases under the No Action Alternative are:

1. Storage in Lake Powell is not allowed to exceed 22.6 maf as of January 1 of each year (before the forecast season) in preparation for storing and regulating spring runoff.

2. On the first of each month from January to June, a protection factor (error term) is added to the forecasted inflow so that more water is assumed to be coming into the reservoir than indicated by the forecast. The error terms follow.

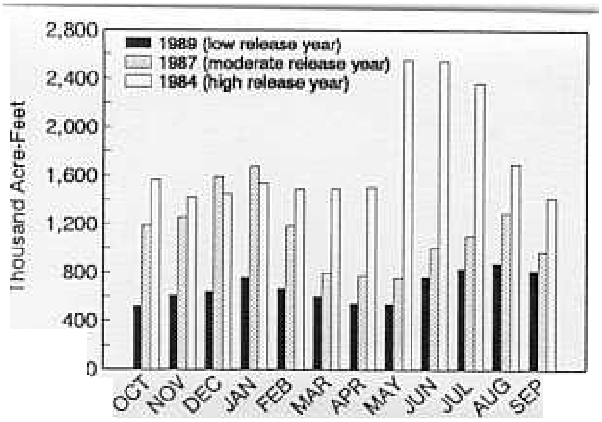


Figure II-3.—Comparison of monthly volumes released during low, moderate, and high release years.

Date	Additional inflow (maf)
January 1	4.98
February	4.26
March 1	3.60
April 1	2.97
May 1	2.53
June 1	2.13

3. Throughout the streamflow forecast season (January 1 to July 1), operations are planned as though Lake Powell has 500,000 acre-feet less capacity than it actually has. This provides a storage buffer to further protect against unforecasted inflow.

Hourly Operations. Hourly releases are set to reach the monthly release volumes, to maintain established minimum flow rates, and to follow the pattern of energy demand. Emergency conditions—such as search and rescue operations, generating equipment failures, or power system emergencies—may cause extreme departures from normal operations. Except for search and rescue operations, these departures are short-lived (generally 1 hour or less), and their effects on water releases can be adjusted in a short time (less than 4 hours).

Hourly power operations are most flexible during months with moderate release volumes. The need to maintain minimum flows in months with low release volumes limits flexibility to accommodate changing hourly power demands. If the reservoir is nearly full and inflow is extremely high, monthly releases are scheduled at or near maximum capacity most of the time, leaving little flexibility for hourly releases to change in response to power demand.

Typical hourly releases for a sample 24-hour period are shown in figure II-2(d). Also, figure II-4 compares 24-hour releases for typical low, moderate, and high release volume days. Fluctuating releases are made when the generating units are being operated to follow changes in power system load, produce peaking power, regulate the power system, or respond to power system emergencies. To the extent possible

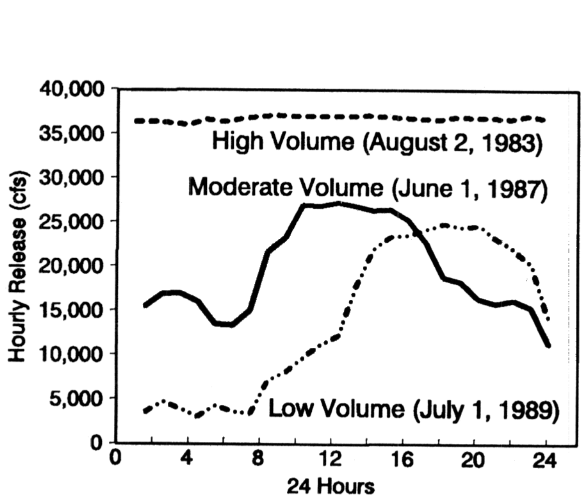


Figure II-4.—Hourly releases for typical summer days with low, moderate, and high release volumes.

within higher priority operating constraints, the following guidelines are used in producing hydroelectric power:

- Maximize water releases during the peak energy demand periods, generally Monday through Saturday between 7 a.m. and 11 p.m.
- Maximize water releases during peak energy demand months and minimize during low demand months
- Minimize and, to the extent possible, eliminate powerplant bypasses

Historic daily ranges of hourly releases are shown for an entire minimum release year in figure II-2(c). During a minimum release year, the greater the daily release volume, the greater the daily fluctuation.

Minimum Flow.–Figure II-5(a) shows the historic distribution of minimum flows. Minimum flows are restricted to no less than 1,000 cfs from Labor Day until Easter and 3,000 cfs from Easter until Labor Day (the recreation season). An additional requirement during the recreation season is that weekday releases average not less than 8,000 cfs for the period from 8 a.m. to midnight. The minimum flow for any given hour typically depends on the monthly release volume and the magnitude and predictability of electrical load

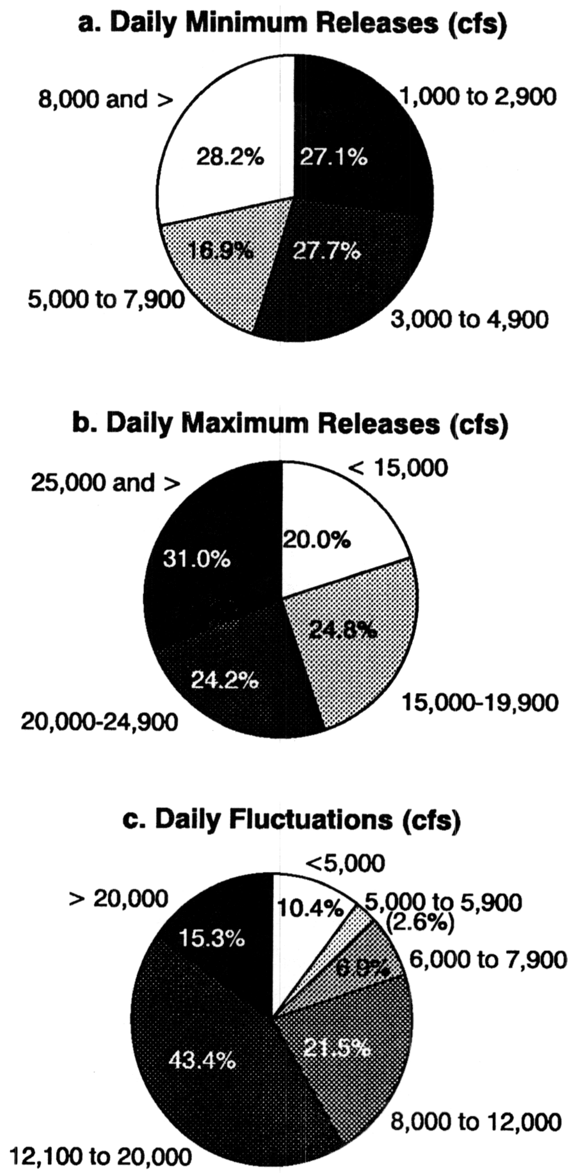


Figure II-5.—Historic distributions of daily minimums, maximums, and fluctuations in cfs (1965-89).

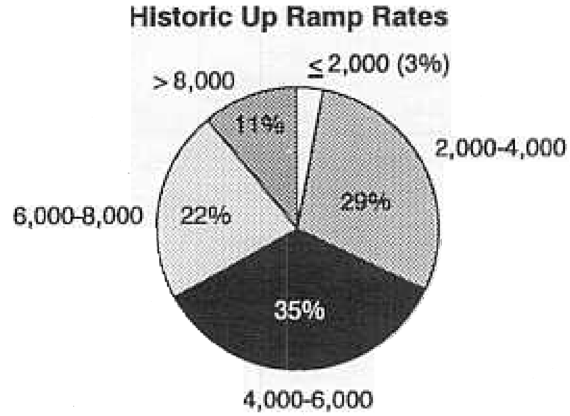
across and within the hour. In some cases, dispatcher experience may be a factor. For a number of reasons (typically for meeting monthly release volumes), minimum flows are frequently above the objective minimum. Occasionally, power system emergencies occur that prevent meeting the minimum release objectives.

Maximum Flow.–The maximum flow is determined by powerplant capacity, the power demand at the time of release, and the amount of water required and/or available for release in a given month. As much as 33,200 cfs can be discharged through the powerplant if the reservoir is at the appropriate elevation. Flows greater than 33,200 cfs are discharged through the outlet works first and then through the spillways, as required. Peak discharges under normal no action operations do not exceed 31,500 cfs. Any releases greater than 31,500 cfs are steady on a daily basis. Figure II-5(b) shows the historic distributions of maximum flows.

Range of Fluctuating Flows.–The range of daily fluctuations under the No Action Alternative is restricted only to between the minimum and maximum flows. Figure II-5(c) shows the historic distribution of daily fluctuations.

Ramp Rate.–The ramp rate is the rate of change in discharge, integrated across the hour, to meet the electrical load by achieving either higher or lower releases. North American Electric Reliability Council (NERC) operating criteria require Western Area Power Administration (Western) to meet scheduled load changes by ramping up or down beginning at 10 minutes before the hour and ending at 10 minutes after the hour. Any ramping to meet scheduled load changes occurs during that same 20-minute period. The principal times of change are in the morning, when releases are ramped upward to respond to the peak daytime demand, and at night, when releases are ramped downward as the electrical demand diminishes.

A computerized automatic generation control (AGC) system controls the rate of release and generation on an instantaneous basis. It also measures the power flow at all electrical interconnections with other control areas. Under historical operations, scheduled ramping has typically resulted in large changes in river stage. However, the continuous small changes in discharge caused by AGC rarely affect river stage by more than a foot. Under the No Action Alternative, the only restriction on ramp rates is the physical capability of the generators. Figure II-6 shows the historic up and down ramp rates. The 1-hour up ramp rates have been less than 4,000 cfs per hour about 32 percent of the time and greater than 8,000 cfs about 11 percent of the time. The down ramp rates have been less than 4,000 cfs about 29 percent of the time and greater than 8,000 cfs about 7 percent of the time.



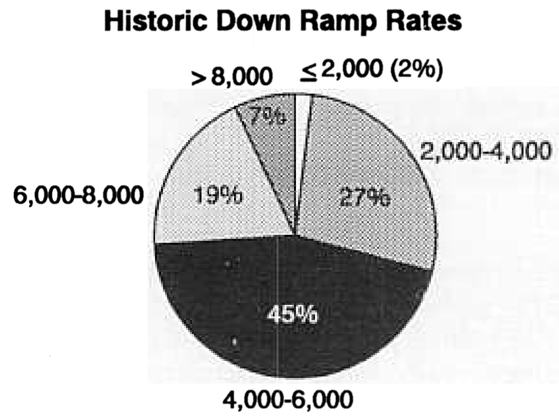


Figure II-6.—Historic (1966-89) distribution of 1-hour ramp rates in cfs per hour. (Maximum daily values for moderate monthly releases of 800,000 acre-feet.)

Maximum Powerplant Capacity Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
1,000 Labor Day to Easter 3,000 Easter to Labor Day	33,200	32,200 Labor Day to Easter 30,200 Easter to Labor Day	Unrestricted

This alternative was developed to allow use of the maximum powerplant discharge capacity that resulted from the 1987 uprate and rewind (see "Background" in chapter I). Operations under the Maximum Powerplant Capacity Alternative would be the same as under the No Action Alternative except that full powerplant capacity (estimated flows of 33,200 cfs) would be allowed. Monthly and annual operations, including flood control, would be identical to those described under the No Action Alternative. Releases in excess of 31,500 cfs would be possible only when Lake Powell's elevation is greater than 3641 feet. This additional capacity would be used when power demand is high and typically would last 4 hours or less (based on historical operations).

Daily and Hourly Operations. Minimum releases would be at least 3,000 cfs from Easter to Labor Day and 1,000 cfs for the remainder of the year. The range in daily release fluctuations and ramp rates would be unrestricted.

Restricted Fluctuating Flows

The restricted fluctuating flow alternatives were designed to provide a range of downstream resource protection measures, while offering varying amounts of flexibility for power operations. All four alternatives—high, moderate, modified low, and interim low fluctuating flows—restrict daily fluctuations at Glen Canyon Dam as compared to the No Action and Maximum Powerplant Capacity Alternatives. Each alternative also specifies ramp rate restrictions and minimum release requirements. Figure II-7 compares operations under these alternatives with historic operations for three different daily water release situations in the peak power month of July.

Within the constraints of the alternatives, maximum water releases would be scheduled to coincide with times of peak electrical demand. Low releases are made at night to maximize the amount of water available for daytime generation and thus minimize expensive daytime power purchases.

For any of the restricted fluctuating flow alternatives, the scheduled annual and monthly release volumes would be determined using essentially the same considerations described under the No Action Alternative. Beach/habitat-building flows would modify monthly release volumes when Lake Powell is drawn down (see "Common Elements").

Habitat maintenance flows—short-term high releases during the spring—are included in the Moderate and Modified Low Fluctuating Flow Alternatives to transport and deposit sand for maintaining camping beaches and fish and wildlife habitat. These maintenance flows were not included in the other restricted fluctuating flow alternatives for the following reasons. With habitat maintenance flows, the High Fluctuating Flow Alternative would, over the long term, move more sand than supplied by tributaries and would result in net erosion. Maintenance flows were not included in the Interim Low Fluctuating Flow Alternative because this alternative was intended to preserve the current interim flow operations for which nearly 2 years of data have been collected.

The common elements that are described later in this chapter apply to all restricted fluctuating flow alternatives.

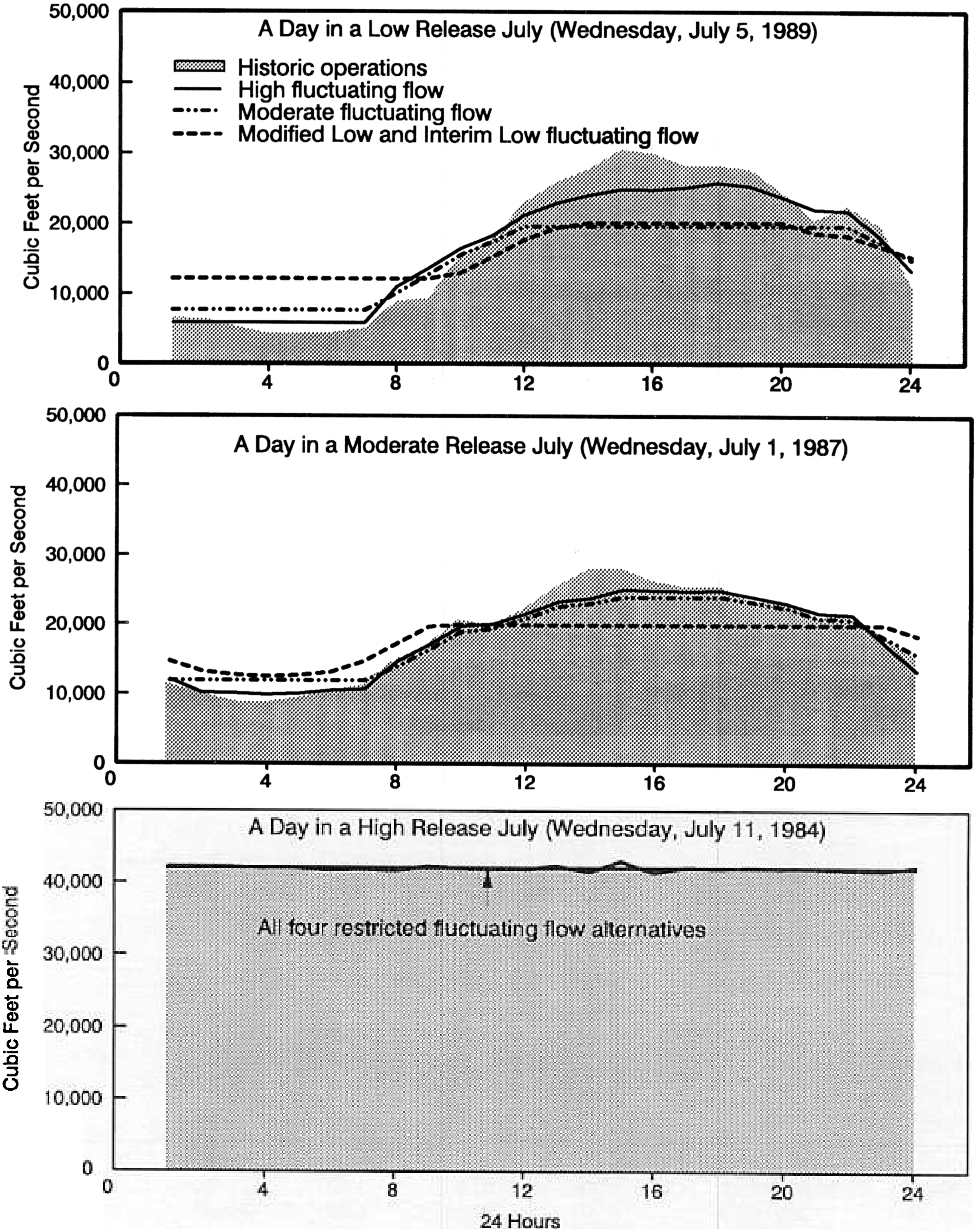


Figure II-7.—Example hourly releases under fluctuating flow alternatives compared to historic operations for low, moderate, and high release days in July. All restricted fluctuating flow alternatives would increase minimum flows and decrease maximum flows when compared to no action.

High Fluctuating Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
3,000 5,000 8,000 depending on monthly volume, firm load, and market conditions	31,500	15,000 to 22,000	Unrestricted up 5,000 or 4,000 down

The High Fluctuating Flow Alternative was developed to slightly reduce fluctuating flows, with the goal of protecting or enhancing downstream resources while allowing flexibility for power operations. Releases would be tied to hydrology and power system demand. This alternative would have the same annual and monthly operation plan as described under the No Action Alternative but would include additional restrictions on daily and hourly operations. Parameters such as minimum flows, down ramp rates, and allowable daily fluctuations were designed to provide some resource protection, but without substantial impacts to hydropower. Although daily fluctuation limits would be constant within a month, the minimum and maximum flows might be different each day.

Daily and Hourly Operations. Minimum flows would be 3,000, 5,000, or 8,000 cfs depending on monthly release volume, firm load, and market conditions (see table II-3). The maximum flow during hourly fluctuating releases would be limited to 31,500 cfs. When high inflow volumes and storage conditions require releases greater than 31,500 cfs, such releases would be steady on a daily basis.

The limit on daily fluctuations often would be more restrictive than the minimum and maximum flow rates. Fluctuations would be limited to 15,000, 20,000, 21,000, or 22,000 cfs over any 24-hour period, depending on the monthly release volume. Maximum flows during a minimum release year normally would not exceed 25,000 cfs. Under this alternative, adverse market conditions (when power demand is relatively high) are assumed to occur during winter and summer: November, December, January, June, July, and August. All other months are considered favorable market condition months (power demand is relatively low).

The ramp rate would follow the power load for increasing flows without restriction, but decreasing flows would be limited to 5,000 cfs per hour in winter and summer and 4,000 cfs per hour during spring and fall.

Table II-3.–Flow parameters under the High Fluctuating Flow Alternative

		Minimum flows				
		Favorable market conditions		Adverse		
		Firm load		market		
Monthly release volume (1,000 acre-feet)	Mean flow (cfs)	>500 GWh[1] (cfs)	<500 GWh (cfs)	conditions (cfs)	Maximum flow (cfs)	Allowable fluctuation (cfs)
<650	<10,900	3,000	3,000	3,000	31,500	15,000
650-850	10,900-14,300	3,000	5,000	3,000	31,500	20,000
850-1,000	14,300-16,800	5,000	8,000	5,000	31,500	21,000
<1,000	>16,800	8,000	8,000	8,000	31,500	22,000
Down ramp rate		4,000 cfs/hr		5,000 cfs/hr		

Moderate Fluctuating Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
5,000	31,500	± 45% of mean flow for the month not to exceed ±6,000	4,000 up 2,500 down

The Moderate Fluctuating Flow Alternative was developed to reduce daily flow fluctuations below no action levels and to provide special high steady releases of short duration, with the goal of protecting or enhancing downstream resources while allowing intermediate flexibility for power operations. This alternative would have the same annual and essentially the same monthly operating plan as described under no action (except for the addition of habitat maintenance flows) but would restrict daily and hourly operations more than the No Action, Maximum Powerplant Capacity, or High Fluctuating Flow Alternatives. Parameters such as minimum flows, ramp rates, and allowable daily fluctuations were designed to provide resource protection through consistent release patterns throughout each month.

Daily and Hourly Operations. Minimum flows for a given month would vary depending on the monthly release volume but would be no less than 5,000 cfs. The maximum release rate for a given month also would vary depending on the monthly release volume but would be no greater than 31,500 cfs under normal operations. When high inflow volumes and storage conditions require releases greater than 31,500 cfs, such releases would be steady on a daily basis. Maximum flows during a minimum release year normally would not exceed 22,300 cfs. The ramp rate would be limited to 4,000 cfs per hour for increasing flows and 2,500 cfs per hour for decreasing flows.

Allowable daily fluctuations as well as minimum and maximum flows would be determined based on the mean releases for the month. The allowable fluctuation would be plus or minus 45 percent of the mean daily flow, not to exceed plus or minus 6,000 cfs. Approximate minimum and maximum release limits and daily fluctuations are as shown in table II-4. The equations used to determine minimum and maximum flows are in attachment 6.

Table II-4.–Flow parameters under the Moderate Fluctuating Flow Alternative

Monthly release volume (acre-feet)	Mean flow (cfs)	Minimum flow (cfs)	Maximum flow (cfs)	Allowable daily fluctuation (cfs)
550,000	9,200	5,100	13,400	±4,150
800,000	13,400	7,400	19,400	±6,000
1,000,000	16,800	10,800	22,800	±6,000
1,500,000	25,200	19,200	31,200	±6,000

Habitat Maintenance Flows. Habitat maintenance flows are included in this alternative to re-form backwaters and maintain sandbars, which are important for camping beaches and fish habitat. Habitat maintenance flows are high, steady releases within powerplant capacity (33,200 cfs) for 1 to 2 weeks in March, although other months would be considered under adaptive management. A more complete description of habitat maintenance flows can be found under the Modified Low Fluctuating Flow Alternative that follows. The monthly release volumes during such flows under this alternative are compared to no action volumes in attachment 6.

Modified Low Fluctuating Flow Alternative (Preferred Alternative)

Minimum releases (cfs)	Maximum releases (cfs)	Daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
8,000 between 7 a.m. and 7 p.m. 5,000 at night	25,000	5,000 6,000 or 8,000	4,000 up 1,500 down

The Modified Low Fluctuating Flow Alternative was developed to reduce daily flow fluctuations well below no action levels and to provide special high steady releases of short duration, with the goal of protecting or enhancing downstream resources while allowing limited flexibility for power operations. This alternative would have the same annual and essentially the same monthly operating plan as described under the No Action Alternative but would restrict daily and hourly operations more than any of the previously described fluctuating flow alternatives.

Additional information on the effects of dam operations has been gathered since the interim operating criteria were developed. Some of this preferred alternative's parameters have changed since the draft EIS was published based on new information and public comments.

To reduce long-term flood frequency, a single method is advanced under this alternative—raising the height of the four spillway gates 4.5 feet to elevation 3704.5 feet (see "Flood Frequency Reduction Measures"). However, since other methods are available to accomplish the same goal, a final decision about the method ultimately used would not be made until additional National Environmental Policy Act (NEPA) compliance has been completed to evaluate environmental impacts on Lake Powell shoreline resources. Lake Powell's current elevation is well below the level that would require reserving additional storage space, thus accomplishing the objective of reducing the frequency of flood releases. The lake level is not expected to reach full elevation for another 4 to 5 years. Until the spillway gates would be installed, additional operational measures would be implemented through the Annual Operating Plan (AOP) process to provide the recommended flood protection.

Daily and Hourly Operations. Minimum flows would be no less than 8,000 cfs between 7 a.m. and 7 p.m. and 5,000 cfs at night. The maximum rate of release would be limited to 25,000 cfs during fluctuating hourly releases. Any releases greater than 25,000 cfs (other than for emergencies) would be steady on a daily basis and would be made in response to high inflow and storage conditions. The limit on daily fluctuations often would be more restrictive than the minimum and maximum flow rates. Fluctuations would be limited during any 24-hour period, depending on monthly release volumes (see table II-5).

Habitat Maintenance Flows. Maximum releases under the Modified Low Fluctuating Flow Alternative normally would not exceed about 20,000 cfs during a minimum release year. Without higher flows:

- Portions of sandbars above the normal peak stage could not be rebuilt.
- Sediment would accumulate at low elevations, including backwaters.
- Camping beaches and return-current channels would likely become filled with sediment and eventually overgrown with vegetation.

Although an occasional floodflow (greater than 33,200 cfs) may rebuild high elevation beaches and re-form backwaters, frequent floodflows would likely transport more sand than could be supplied by the tributaries—resulting in long-term sandbar erosion. Therefore, habitat maintenance flows are included in this alternative to re-form backwaters and maintain sandbars, which are important for camping beaches and wildlife habitat.

Table II-5.–Flow parameters under the Modified Low and Interim Low Fluctuating Flow Alternatives

Monthly release volume (acre-feet)	Mean flow (cfs)	Minimum flow (cfs)	Maximum flow[1] (cfs)	Allowable daily fluctuation (cfs)
<600,000	<10,100	5,000/8,000	25,000	5,000
600,000-800,000	10,100-13,400	5,000/8,000	25,000	6,000
>800,000	>13,400	5,000/8,000	25,000	8,000

[1] Does not include habitat maintenance flows.

Habitat maintenance flows are high, steady releases within powerplant capacity (33,200 cfs[1]) for 1 to 2 weeks in March, although other months would be considered under the Adaptive Management Program. March was selected for the following reasons:

Backwater channels could be re-formed prior to the humpback chub spawning period.

More sediment is likely to be supplied by tributary flow in March than later in the spring.

March is prior to the peak recreation use season.

Habitat maintenance flows would not be scheduled when the projected storage in Lake Powell on January 1 is greater than 19 maf. Annual release volumes under such conditions are typically greater than the minimum annual release volume (8.23 maf), and such flows already may be near or exceed powerplant capacity.

Although habitat maintenance flows are defined as steady, minor fluctuations of up to plus or minus 1,000 cfs would be permitted to regulate voltage within the power grid. Maintenance flows would begin by increasing flows at a rate no greater than 4,000 cfs per hour and would conclude by decreasing flows back to the normal operating range at a rate no greater than 1,500 cfs per hour. The limit on daily change in flow would not apply during these transitions.

Habitat maintenance flows would differ from beach/habitat-building flows (a common element of the restricted fluctuating and steady flow alternatives) because they would be within powerplant capacity and would occur nearly every year when the reservoir is low. Beach/habitat-building flows would be of greater magnitude than habitat maintenance flows and would be less frequent. Habitat maintenance flows would not occur in years when a beach/habitat-building flow is scheduled (see discussion under "Common Elements" later in this chapter). Neither of these special releases would be scheduled in a year when there is concern for a sensitive resource—such as sediment or an endangered species.

Increasing the flow to 30,000 cfs for 10 days would result in the release of an additional 412,000 acre-feet of water in March, which would require adjusting the release volumes in the other months. This scheduling adjustment would be determined during the Annual Operating Plan preparation and may vary from year to year. The monthly release volumes under this alternative are compared to no action volumes in attachment 6.

Endangered Fish Research. The endangered fish research described under this alternative in the draft EIS has been moved to the scientifically based Adaptive Management Program (see discussion under "Common Elements" later in this chapter).

Interim Low Fluctuating Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
8,000 between 7 a.m. and 7 p.m. 5,000 at night	20,000	5,000 6,000 or 8,000	2,500 up 1,500 down

The Interim Low Fluctuating Flow Alternative was developed to reduce daily flow fluctuations well below no action levels, with the goal of protecting or enhancing downstream resources while allowing limited flexibility for power operations. This alternative would have the same annual and monthly operating plan as the No Action Alternative but would restrict daily and hourly operations as much as or more than under any alternative allowing fluctuating flows.

Actual powerplant release capacity may be less under low reservoir conditions.

This alternative is the same as the interim operating criteria implemented on November 1, 1991 (except for the addition of the common elements). Interim operating criteria were established prior to obtaining results from GCES Phase II. Parameters such as minimum flows, maximum flows, ramp rates, and allowable daily fluctuations were designed to protect downstream resources until completion of the final EIS and record of decision (ROD).

Daily and Hourly Operations. Minimum flows would be no less than 8,000 cfs between 7 a.m. and 7 p.m. and 5,000 cfs at night. The maximum rate of release would be limited to 20,000 cfs during fluctuating hourly releases. Any releases greater than 20,000 cfs (other than for emergencies) would be steady on a daily basis and would be made in response to high inflow and storage conditions.

The limit on daily fluctuations often would be more restrictive than the minimum and maximum flow rates. Fluctuations would be limited during any 24-hour period, depending on monthly release volumes.

Steady Flows

The steady flow alternatives were designed to provide a range of downstream resource protection measures by minimizing daily release fluctuations. Flows would be steady on either a monthly, seasonal, or year-round basis. The monthly distribution of release volumes would differ, but daily and hourly operating criteria would be the same for all steady flow alternatives. Flows would be the same each day within the month or season (except during flood control operations). Figure II-8 compares operations under the steady flow alternatives with historic operations for low (8.23 maf), moderate (13.6 maf), and high (21.1 maf) release years. The scheduled annual release volume would be determined in accordance with the Long-Range Operating Criteria.

Monthly or seasonal release volumes would be based on the month-to-month pattern specified for the alternative. Although the goal would be to maintain steady (uniform) water releases for selected durations, the ability to maintain a steady flow from one period to the next would depend on the accuracy of streamflow forecasts and the space available in Lake Powell.

Minimum or maximum flow rates would be determined by the monthly water volume to be released. The goal would be to hold flows steady to within plus or minus 1,000 cfs per day and adjust them between months in response to forecast changes. Ramp rates within this flow range would not be restricted because river stage fluctuations would be within a few inches. The maximum change in releases between months would be 2,000 cfs per day.

Daily variations of plus or minus 1,000 cfs per day (approximately 42 megawatts) would allow some minor flexibility in dam operations to be used primarily for electrical system regulation. AGC would cause minor fluctuations as the powerplant's computerized regulation system made adjustments every 2 to 6 seconds. Resulting changes in river stage would not be noticeable downstream. Flow fluctuations of this magnitude were measured during steady research flows, and the corresponding river stage fluctuations were small (see figure II-9).

Water releases in excess of powerplant capacity would flow through the outlet works and/or spillways during high water years or, as necessary, during beach/habitat-building flows.

The habitat maintenance flows included in the Seasonally Adjusted Steady Flow Alternative were not included in the other steady flow alternatives. Such flows would be contrary to the concepts for which these steady flow alternatives were developed, i.e., to keep flows steady under the Year-Round Steady Flow Alternative and to retain the pattern of historic monthly releases under the Existing Monthly Volume Steady Flow Alternative.

The "Common Elements" described later in this chapter apply to all steady flow alternatives.

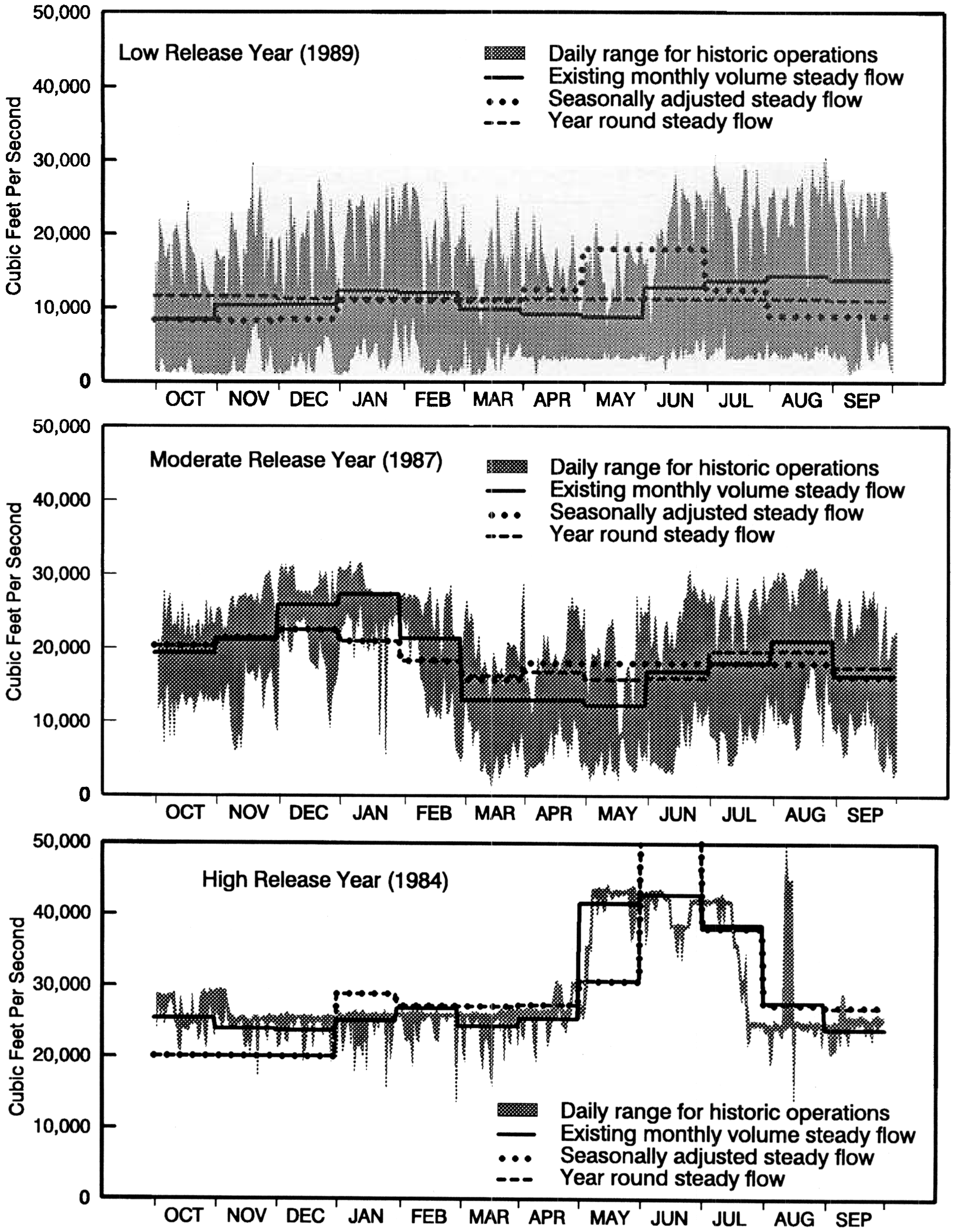


Figure II-8.—Steady flow alternatives compared to no action for low, moderate, and high release years.

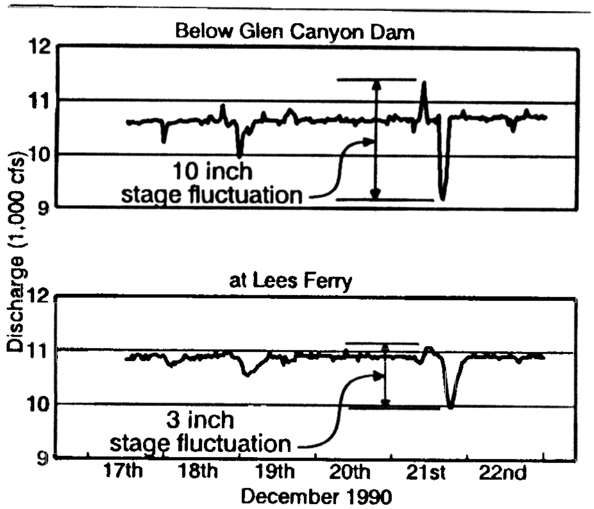


Figure II-9.—Changes in electrical load during steady research flows caused minor discharge fluctuations that were measured at U.S. Geological Survey gauging stations below the dam and at Lees Ferry. On December 21, the 2,170-cfs fluctuation measured 1/2 mile below the dam was reduced to 1,105 cfs at Lees Ferry. This release fluctuation resulted in a river stage fluctuation of 10 inches at the gauge below the dam and 3 inches at the Lees Ferry gauge.

Existing Monthly Volume Steady Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/day)
8,000	Monthly volumes prorated	±1,000	2,000 between months

The Existing Monthly Volume Steady Flow Alternative was developed to provide steady flow on a monthly basis while continuing to maintain flexible monthly release volumes to avoid spills and maintain conservation storage. Steady flows were included each month with the goal of protecting or enhancing downstream resources, especially the aquatic ecosystem that exists downstream from the dam.

This alternative would have the same annual and monthly operating plan as the No Action Alternative, but releases would be steady within months. Also, beach/habitat-building flows would modify monthly release volumes when Lake Powell is drawn down (see "Common Elements"). See figure II-8 for estimated operations under this alternative, using historic low, moderate, and high annual release situations.

Minimum Flow. Both minimum and maximum flows would be within plus or minus 1,000 cfs of the mean monthly release. Based on analysis of historical releases, minimum flows would rarely be below 8,000 cfs (476,000-acre-foot monthly volume).

Monthly Release Volume. The scheduled monthly release volumes would be the same as the monthly volumes under the No Action Alternative. Based on the period 1963-89, February has the lowest monthly median release volume (556,000 acre-feet—equivalent to 10,000 cfs), and August has the highest monthly median release volume (903,000 acre-feet—equivalent to 14,700 cfs).

Seasonally Adjusted Steady Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/day)
8,000 Oct-Nov 8,500 Dec 11,000 Jan-Mar 12,500 Apr 18,000 May-Jun 12,500 Jul 9,000 Aug-Sep	18,000	±1,000	2,000 between months

The Seasonally Adjusted Steady Flow Alternative was developed to enhance the aquatic ecosystem by releasing water at a constant rate within defined seasons and by using habitat maintenance flows. Seasonal variations in minimum flows and habitat maintenance flows were designed with the goal of protecting and enhancing native fish. See figure II-8 for estimated operations under this alternative. Monthly release patterns would differ from the No Action Alternative as explained in more detail below.

This alternative would provide steady flows on a 1- to 3-month basis, providing seasonal variations throughout the year to meet downstream resource needs. The highest releases would occur in May and June, with relatively low releases from August through December.

Minimum Flow. The minimum monthly constant release for each season is shown above. These minimum release requirements would be relaxed to avoid spills during high storage or inaccurate forecast situations.

Monthly Release Volume. Releases within each month would be steady and would have to equal or exceed the monthly minimums. Any additional water in excess of the minimum annual release volume would be distributed equally among the 12 months, subject to an 18,000-cfs maximum. This 18,000-cfs maximum would be exceeded when the annual release is more than 13.14 maf. If forecasts changed, the volume of water to be released during the remainder of the year would be recomputed monthly based on updated forecasts, and the constant rate of release would be adjusted accordingly.

Habitat Maintenance Flows. Habitat maintenance flows are included in this alternative to re-form backwaters and maintain sandbars. Habitat maintenance flows are high, steady releases within powerplant capacity (33,200 cfs) for 1 to 2 weeks in March, although other months would be considered under the Adaptive Management Program. A more detailed discussion of habitat maintenance flows can be found under the Modified Low Fluctuating Flow Alternative.

The monthly release volumes during habitat maintenance flows under this alternative are compared to no action volumes in attachment 6.

Year-Round Steady Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/day)
Yearly volume prorated	Yearly volume prorated	±1,000	2,000 between months

The Year-Round Steady Flow Alternative was developed to eliminate fluctuating flows, both daily and seasonal. Year-round steady flows were designed with the goal of protecting or enhancing downstream resources by providing the greatest amounts of river-stored sediment and biomass possible in the postdam environment.

Minimum Flow. The minimum flow would be determined from the mean monthly release but would correspond generally to the minimum annual release volume of 8.23 maf, which is about 11,400 cfs. The minimum release requirement would be relaxed to avoid spills during high storage or inaccurate forecast situations.

Monthly Release Volume. The monthly volume would be approximately the annual volume divided by 12, except when response to forecast changes would be required. If forecasts changed, the volume of water to be released during the remainder of the year would be recomputed monthly based on updated forecasts, and the constant rate of release would be adjusted accordingly. The ability to maintain a constant rate of release for the entire year would depend on the accuracy of streamflow forecasts and the amount of space remaining in Lake Powell. Approximately half of the time, lake elevation would be high enough that forecast changes could cause some variations in monthly volumes.

Common Elements

The elements common to all restricted fluctuating flow and steady flow alternatives are described in detail below. Impact analyses of these alternatives were conducted taking these common elements into account.

Adaptive Management

The completion of the Glen Canyon Dam EIS process will result in a decision by the Secretary of the Interior (Secretary) on the operation of Glen Canyon Dam. It is intended that the ROD will initiate a process of "adaptive management," whereby the effects of dam operations on downstream resources would be assessed and the results of those resource assessments would form the basis for future modifications of dam operations. Many uncertainties still exist regarding the downstream impacts of water releases from Glen Canyon Dam. The concept of adaptive management is based on the recognized need for operational flexibility to respond to future monitoring and research findings and varying resource conditions.

The Adaptive Management Program (AMP) was developed and designed to provide an organization and process for cooperative integration of dam operations, resource protection and management, and monitoring and research information. The program would meet the purpose and strengthen the intent for which this EIS was prepared and ensure that the primary mandate of the Grand Canyon Protection Act of 1992 (GCPA) is met through future advances in information and resource management.

The Secretary of the Interior will issue a ROD outlining criteria and operating plans resulting from this EIS and exercise other measures and authorities under existing law, as appropriate, to ensure that Glen Canyon Dam is operated in a manner consistent with section 1802 of the GCPA. It is expected that the AMP would be implemented as an element of the ROD and would provide the basis and process for developing an annual report to the Congress and Governors of the Colorado River Basin States. The annual report would outline the operations undertaken in the current and projected years pursuant to the GCPA.

The AMP is not intended to satisfy all of the mandates in the GCPA. Likewise, the program is not intended to derogate any agency's statutory responsibilities for managing certain resources. For example, operation of Glen Canyon Dam is the Bureau of Reclamation's (Reclamation) responsibility, and Reclamation cannot relegate this authority to any other entity. The AMP would recommend other administrative provisions, but these recommendations would in no way supersede the basic management responsibilities of any of the cooperating entities.

The purpose of the AMP would be to develop modifications to Glen Canyon Dam operations and to exercise other authorities under existing laws as provided in the GCPA to protect, mitigate adverse impacts to, and improve the values for which the Glen Canyon National Recreation Area and Grand Canyon National Park were established. These values include, but are not limited to, natural and cultural resources and visitor use. Physical and economic conditions must also be considered in any proposed modification to dam operations. Long-term monitoring and research are essential to adaptive management and would be implemented to measure how well the selected alternative meets resource management objectives (see Appendix A, Long-Term Monitoring and Research).

Authority. The AMP would be implemented consistent with the Grand Canyon Protection Act which requires the Secretary to:

> (a) Adopt criteria and operating plans separate from and in addition to those specified in section 602(b) of the Colorado River Basin Act of 1968 and exercise other authorities under existing laws, so as to ensure that Glen Canyon Dam is operated consistent with section 1802 and to fulfill consultation requirements of section 1804(c) of the GCPA.
>
> (b) Establish and implement long-term monitoring and research programs and activities that will ensure that Glen Canyon Dam is operated in accordance with provisions of section 1802 and consultation requirements of section 1805(c).

In carrying out such provisions, the Secretary or his designee would develop, as appropriate, modifications to operating criteria or other management actions in consultation with all interested parties and an Adaptive Management Work Group (AMWG). The process would include coordination of formal consultation required in sections 1804(c) and 1805(c) of the GCPA concerning additional operating criteria for Glen Canyon Dam and long-term monitoring and research programs, respectively. In addition, all program activities would comply with applicable laws and permitting requirements.

Consultation would be maintained with appropriate agencies of the Department of the Interior, including the U.S. Fish and Wildlife Service, National Park Service (NPS), Bureau of Reclamation, and Bureau of Indian Affairs; the Secretary of Energy; Governors of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming; Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Navajo Nation, Pueblo of Zuni, San Juan Southern Paiute Tribe, Southern Paiute Consortium; and the general public, including representatives of academic and scientific communities, environmental organizations, the recreation industry, and contractors for the purchase of Federal power produced at Glen Canyon Dam.

Principles. The principles that guided the design of the AMP organization and process are:

Monitoring and research programs should be designed by qualified researchers in direct response to the needs of management agencies.

A process is required to coordinate and communicate management agency needs to researchers and to develop recommendations for decisionmaking.

A forum is required for the transfer of monitoring and research investigation results to the management agencies and to develop consensus on management response to information on affected resource conditions, trends, and processes.

- All monitoring and research programs in Glen and Grand Canyons should be independently reviewed.
- Interested parties identified in the GCPA should be provided opportunity for full and timely participation in proposals and recommendations.

Specific AMP goals include:

- Facilitating management response to monitoring and research information on affected resource conditions, trends, and processes
- Ensuring compliance with section 1802 of the GCPA and the statutory purposes for Glen Canyon Dam (the "Law of the River"), Grand Canyon National Park, and Glen Canyon National Recreation Area
- Assuring resource management obligations are defined and fulfilled in good faith without abridgment of any Federal, State, Tribal, or other legal obligation
- Providing a mechanism for resolving disputes

Transition Period and Funding. Reclamation would continue to provide staff and funding for administering interim flow monitoring and ongoing research programs until the ROD is issued and/or the AMP has been implemented. It is anticipated that monitoring and research functions would be transferred to a monitoring and research center during late fiscal year 1995 and early 1996. The GCES Senior Scientist would direct this transition to assure continuity and efficient transfer of the GCES into the long-term program. Subsequently, Reclamation would continue to allocate funds for administration and monitoring and research as outlined in sections 1807 and 1808 of the GCPA. The funding of other management actions would be the responsibility of the agency administering the affected resource.

Organization. The Adaptive Management Program would be administered through a senior Department of the Interior official (designee) and facilitated through an Adaptive Management Work Group organized as a Federal Advisory

Committee. The AMWG would be chaired by the designee and supported by a monitoring and research center and technical work group. Independent review panels would provide overview of technical studies and evaluations. Figure II-10 shows the organizational structure of the AMP.

The program would be directed by the designee, who would serve as the Secretary's principal contact for the AMP and as the focal point for issues and decisions associated with the program. Responsibility would include ensuring that the Department of the Interior complies with its obligations under the GCPA and ROD for this EIS. The designee would review, modify, accept, or remand the recommendations from the AMWG in making decisions about any changes in dam operation and other management actions.

Adaptive Management Work Group.– The AMWG membership would be appointed by the Secretary with representation from each of the cooperating agencies associated with this EIS, each of the Colorado River Basin States, and two representatives each from environmental groups, recreation interests, and contractors for Federal power from Glen Canyon Dam. It is recommended that the representation from the latter three interest groups be on a 2-year rotating basis to allow more diverse participation. The AMWG would make recommendations to the Secretary's

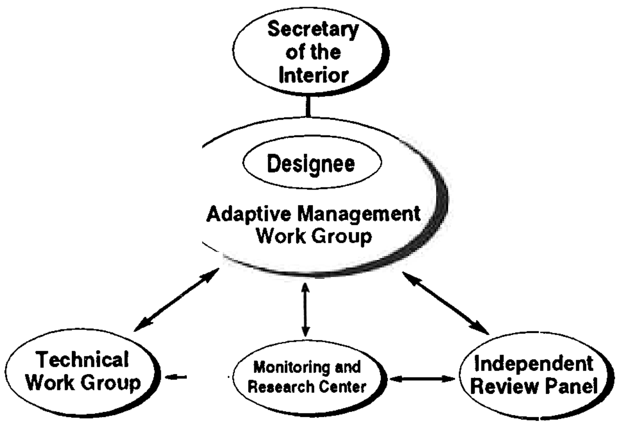


Figure II-10.—Organizational structure of the Adaptive Management Program.

designee and facilitate consultation with all interests. Non-Government representatives would be reimbursed for travel and related expenses for activities and meetings of the AMWG in accordance with provisions of the Federal Advisory Committee Act, the AMWG charter, and other existing laws. The work group would:

- Provide the framework for AMP policy, goals, and direction
- Develop recommendations for modifying operating criteria and other resource management actions
- Facilitate coordination and input from interested parties
- Review and forward the annual report to the Secretary and his designee on current and projected year operations
- Review and forward annual budget proposals
- Ensure coordination of operating criteria changes into the Annual Operating Plan for Colorado River Reservoirs and other ongoing activities

The following organizational elements are proposed.

1. *Monitoring and Research Center*: To support the designee and the AMWG, it is recommended that the Secretary establish a research center within the U.S. Geological Survey (USGS) and/or National Biological Service with a small permanent staff in Flagstaff, Arizona. The center would be responsible for developing the annual monitoring and research plan, managing all adaptive management research programs, and managing all data collected as part of those programs. All adaptive management research programs would be coordinated through the center.

Long-term monitoring and research associated with cultural resources would be carried out in accordance with the approved Programmatic Agreement on Cultural Resources (attachment 5). All provisions as agreed upon by the consulting parties would be implemented through the Monitoring and Remedial Action Plan and the Historic Preservation Plan. Activities outlined in these documents would be coordinated through the center to ensure integration with other facets of the long-term monitoring and research program.

The center's administrative responsibilities would include managing resource data, reporting monitoring and research results, administering contracts, and developing annual reports. The center would emphasize long-term monitoring and research design, integration, and program management. It would be staffed by a research director and a group of program managers responsible for functions such as physical science, biological science, cultural resources, social sciences, engineering and infrastructure operations, and Native American coordination. The research director would be selected by the Secretary or his designee from a list of candidates provided through Federal hiring authorities with recommendations by the National Academy of Sciences, Indian Tribes, and other members of the AMWG. The position would reside with the National Biological Service and/or the USGS at the GS-14/15 level.

The Native American coordinator would facilitate and manage monitoring and research related to tribal needs. The coordinator also would ensure integration of tribal concerns with all other monitoring and research elements.

The center's programs associated with long-term monitoring and research would be funded by power revenues and coordinated through the Reclamation budget process. However, professional staffing for the center would be provided by USGS, National Biological Service, and the participating agencies in the AMWG. The center would closely coordinate its activities with the Technical Work Group. The following specific duties would be assigned to the Monitoring and Research Center:

Develop research designs and proposals for implementing monitoring and research identified by the AMWG

Manage all monitoring and research on resources affected by dam operations

- Manage and maintain the GCES information data base, monitoring and research programs, and other data sources as appropriate
- Administer research proposals through a competitive contract process, as appropriate
- Coordinate, prepare, and distribute technical reports and documentation for review and as final products
- Coordinate review of the monitoring and research program with the independent review panel(s)
- Prepare and forward technical management recommendations and annual reports, as specified in section 1804, to the AMWG

2. *Technical Work Group*: This work group would be comprised of technical representatives from Federal, State, and Tribal Governments, and other interests represented on the AMWG. The Technical Work Group would be appointed by the member agencies or interests represented on the AMWG. The group would translate AMWG policy and goals into resource management objectives and establish criteria and standards for long-term monitoring and research in response to the GCPA. These would then be used by the center in developing appropriate monitoring and research. The Technical Work Group would meet two to four times annually, as necessary.

It is recommended that the Secretary or his designee appoint the chair for the group on a 2-year rotating basis, giving consideration to the dominant or most pressing issues. The Technical Work Group would:

- Develop criteria and standards for monitoring and research programs within 3 months of the formation of the group and provide periodic reviews and updates
- Develop resource management questions for the design of monitoring and research by the center
- Provide information as necessary for preparing annual resource reports and other reports as required for AMWG

3. *Independent Review Panel(s)*: The Independent Review Panel(s) would be comprised of qualified individuals not otherwise participating in the

long-term monitoring and research studies. The review panel(s) would be established by the Secretary of the Interior in consultation with the National Academy of Sciences, the tribes, and other AMWG entities. The review panel(s) would be responsible for periodically reviewing resource specific monitoring and research programs and for making recommendations to the AMWG and the center regarding monitoring, priorities, integration, and management. Responsibilities of this review panel would include:

- Annual review of the monitoring and research program
- Technical advice as requested by the center or AMWG
- Five-year review of monitoring and research protocols

Dispute Resolution. Recommendations would be formulated by the AMWG and forwarded to the Secretary's designee. In the event that one or more entities do not support the recommendation, the views or concerns of the nonconcurring interests would accompany the recommendation for consideration in the decision.

Endangered Fish Research. It has been determined through Endangered Species Act consultation with FWS that the studies outlined below are necessary and would be undertaken through the Adaptive Management Program.

Endangered and other native fish in Grand Canyon are commonly thought to be limited by cold, clear water releases from Glen Canyon Dam; large daily flow fluctuations; and non-native fish. However, uncertainty remains regarding the impacts of dam operations on fish. Although a considerable amount of research on endangered fish has been conducted, there has been no opportunity to study the effects of low, steady flows in summer and fall combined with higher, steady spring flows—which FWS believes are critical to native fish in the Colorado River. Therefore, studies to include endangered fish research flows would be coordinated with the long-term monitoring and research under the AMP. These studies would be carried out in accordance with the reasonable and prudent alternative developed by FWS in their biological opinion (see attachment 4).

A set of research hypotheses and specific flows or experiments to test these hypotheses would be developed. Concurrently, a risk assessment of the flows would be conducted using existing literature and data and laboratory experiments. Results from the risk assessment may lead to reopening Endangered Species Act consultation between Reclamation and FWS.

When implemented, the research flows would require as many as 5 low release years (annual release at or near 8.23 maf). Since low water release years are expected to occur only about half the time, it is uncertain how many total years it would take to complete the research program. However, it is likely that research flows could be completed within 10 years. The ideal situation would call for uninterrupted research occurring during consecutive low release years.

Endangered fish research flows would be between 8,000 and 20,000 cfs with a spring through fall pattern and monthly release volumes similar to the Seasonally Adjusted Steady Flow Alternative. Results from the research program would be monitored, and corrective action would be taken if adverse effects on endangered species were identified. Upon completion of the research flows and analysis of the data, Reclamation would implement any necessary changes in operating criteria to comply with the Endangered Species Act through the AMP.

Monitoring and Protecting Cultural Resources

The existence and operation of Glen Canyon Dam has had an effect on the historic properties within the Colorado River corridor of Glen and Grand Canyons. These properties include prehistoric and historic archeological sites, along with Native American traditional cultural places and sacred sites. Impacts are likely to occur to some of these historic properties regardless of the EIS alternative chosen for implementation.

The National Historic Preservation Act requires Federal agencies to consider measures which would avoid or minimize loss of historic properties resulting from their actions. Due to the potential impact from any dam operation, Federal agency responsibilities for compliance with sections 110 and 106 of the National Historic Preservation Act will be required for each alternative considered in this document.

Given the potential impacts of the existence and operation of Glen Canyon Dam, Reclamation and NPS have complied with documentation requirements in established regulations (36 Code of Federal Regulations 800). The Advisory Council on Historic Preservation, Arizona State Historic Preservation Officer, Reclamation, NPS, and Indian Tribes completed a programmatic agreement which ensures that both Reclamation's section 106 responsibilities and NPS's section 110 responsibilities are satisfied (see attachment 5). Administration, implementation, and refinement of the program design are detailed in the programmatic agreement and accompanying monitoring and historic preservation plans.

The programmatic agreement and accompanying plans will direct long-term monitoring, which includes continuing consultation, identification, inspection, analysis, evaluation, and remedial protection actions as necessary to preserve the historic properties within Glen and Grand Canyons.

Potential remedial actions would be initiated in consultation with all of the Federal and State agencies and Indian Tribes involved in the agreement. A range of actions are proposed, which are presented in the Monitoring and Remedial Action Plan in attachment 5.

This ongoing consultation process and revision of preservation plans to maintain the integrity and stability of the properties should help to minimize the impacts of Glen Canyon Dam operations on cultural resources.

The NPS will prepare agreements with all of the affected tribes as required by the Native American Graves Protection and Repatriation Act (1990). Reclamation will develop agreements with the Navajo Nation and Hualapai Tribe for the treatment of human remains that may be affected on their lands.

Flood Frequency Reduction Measures

Although infrequent floodflows may be considered beneficial to downstream resources, frequent or unscheduled floods, particularly those of long duration, are damaging to downstream resources. Under this common element, the frequency of unscheduled floodflows greater than 45,000 cfs would be reduced to no more than 1 year in 100 years as a long-term average. This would allow for the management of the habitat maintenance flows and beach/habitat-building flows described later in this section. Floodflow frequency of once in 100 years is considered rare enough for resource needs, while not imposing unreasonable requirements on Lake Powell water storage.

Two separate methods of reducing flood frequency have been identified. These methods focus on reserving additional storage space for flood control.

1. Increase the capacity of Lake Powell 0.75 maf by raising the height of the four spillway gates 4.5 feet to elevation 3704.5 feet (currently, each gate is 40 feet wide and 52.2 feet high). This additional capacity would be nonviolable flood control space and would be used only in years when existing flood protection measures were insufficient. Construction of this project would cost about $3 million. No permits under the Clean Water Act or Rivers and Harbors Act would be required to implement this element.

2. Change releases to target a maximum reservoir content of 23.3 maf (1 maf less than the current active capacity) in the spring until the runoff peak has clearly passed. This additional space would allow improved management of late-season forecast errors, the primary cause of flood releases that exceed 45,000 cfs. The amount

of required vacant space in the spring months would eventually decrease as Upper Basin depletions increase.

By implementing either flood protection measure, additional reserved reservoir space would be available from January 1 through July 1 to store any additional unforecasted inflow.

Beach/Habitat-Building Flows

Under any EIS alternative, Grand Canyon sandbars that exist above the normal peak river stage would continue to erode, and backwater habitat within normal stage would tend to fill with sediment. Therefore, beach/habitat-building flows have been incorporated as an element common to all restricted fluctuating and steady flow alternatives.

Beach/habitat-building flows would be scheduled high releases of short duration designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system.

Magnitude. Replenishing sandbars requires both an available upstream sand supply and higher than normal flows to deposit sand at high elevations. Sandbars must be several feet above the water surface to be dry and suitable for wildlife habitat or camping. Consequently, sandbars must be deposited and formed by discharges somewhat higher than the normal operating range.

Magnitudes would be at least 10,000 cfs greater than the allowable peak discharge in a minimum release year for a given alternative but not greater than 45,000 cfs (see table II-6). Graphs presented by Leopold (1969) show that during the flood of 1948, flows of about 45,000-50,000 cfs were needed to initiate movement of substantial amounts of sand from the riverbed at Lees Ferry. Burkham (1987) provided understanding of the flows necessary to degrade the riverbed and thus initiate movement of sand and coarser sediment—depending on the amount of sand stored on the riverbed. Andrews (1991b) reported that 40,000-45,000-cfs flows would be required in order to rebuild sandbars. Deposition rates calculated by Andrews are about 0.5 centimeter per day at 20,000 cfs and about 8 centimeters per day at 40,000 cfs.

As part of the Adaptive Management Program, a test of a beach/habitat-building flow would be conducted prior to long-term implementation of this element to test the predictions made in

Table II-6.–Example beach/habitat-building peak discharges and monthly volumes

Alternative	Allowable peak discharge[1] (cfs)	Beach/ habitat-building flow (cfs)	Original volume (acre-feet)	Additional volume required (acre-feet per month)	Reductions from other months (acre-feet per month)
Restricted fluctuating flow					
High	31,500	41,500	607,000	627,000	57,000
Moderate	30,000	40,000	607,000	598,000	54,300
Modified low	30,000	40,000	607,000	598,000	54,300
Interim low	20,000	30,000	607,000	399,000	36,300
Steady flow					
Existing monthly volume	14,400	24,400	607,000	288,000	26,200
Seasonally adjusted	30,000	40,000	687,000	572,000	52,000
Year-round	11,400	21,400	695,000	200,000	18,200

[1] Minimum release year (8.23 maf) without a beach/habitat-building flow.

chapter IV. Scheduled flows exceeding powerplant capacity (33,200 cfs) may require legislation to implement.

Ramp Rates. Releases would be increased at a maximum rate of 4,000 cfs per hour and decreased at a maximum rate of 1,500 cfs per hour.

Season and Duration. Beach/habitat-building flows could be scheduled in the spring (to coincide with the May/June peak in the natural hydrologic cycle) or in late summer when, due to local thunderstorms, tributaries are expected to supply large quantities of sediment (especially silt and clay) and nutrients. Initially, beach/habitat-building flows would be scheduled in early spring for a duration of 1 to 2 weeks. The duration would be long enough to substantially rebuild sandbars, considering the deposition rates estimated by Andrews (1991b) but would be constrained by the volume of water available. The exact season and duration would be determined through adaptive management. Releases would be curtailed if monitoring showed detrimental impacts to the ecosystem. A 10-day flow in March/April is assumed when describing the environmental consequences in chapter IV.

Water Year and Frequency. A recommendation for a beach/habitat-building flow would come from the AMP, and such a flow would be scheduled as part of the Annual Operating Plan (developed in the summer for the following water year). Such flows would be scheduled only in years when the projected storage in Lake Powell on January 1 is less than 19 maf (low reservoir condition). Scheduling beach/habitat-building flows during high reservoir conditions would be avoided because of the increased risk of unscheduled flows greater than powerplant capacity (see attachment 6).

A beach/habitat-building flow would be recommended during years when sufficient quantities of sediment are available, but not following a year in which a large population of young humpback chub is produced (see chapter III, FISH). A frequency of 1 in 5 years (when the reservoir is low) was assumed for analyzing the environmental consequences presented in chapter IV. Although these flows would be expected to aggrade many sandbars, these sandbars would be subject to natural erosion. How long these new deposits would last would be determined through monitoring.

Monthly Release Volumes. Additional water would be scheduled in March/April to support a beach/habitat-building flow. The additional release volumes needed in March/April and the volume to be taken from other months would vary by alternative (see table II-6) and would be developed under the AOP.

New Population of Humpback Chub

The Grand Canyon population of humpback chub uses habitats in both the Colorado River mainstem and the Little Colorado River (LCR). Conditions in the mainstem (principally water temperatures) are not conducive to humpback chub spawning or survival of eggs and young. An aggregation of humpback chub may now be reproducing in the mainstem near river mile 30 (Valdez and Ryel, in preparation); however, the numbers are small and evidence is inconclusive. The only confirmed successful spawning habitat for that population is in the LCR, with individuals moving between that tributary and the mainstem.

Since the only known humpback chub population in the Lower Colorado River Basin depends on the LCR for survival, a catastrophic event or a series of incidents that would reduce the viability of this spawning habitat could cause the loss of this population. This possibility will persist until or unless:

1. At least one more population is established in the mainstem or one or more of the tributaries below Glen Canyon Dam, and/or

2. Mainstem water temperatures are sufficiently warmed to support spawning and recruitment

Therefore, in consultation with FWS, NPS, Arizona Game and Fish Department (AGFD), and other land management entities such as the Havasupai Tribe, Reclamation would make every effort—through funding, facilitating, and technical support—to establish a new population of humpback chub within Grand Canyon. Such efforts will necessitate a feasibility assessment to report the natural distribution of the fish and the appropriateness of any ecosystem manipulation being considered. Policy implications for the affected parties would be reviewed as part of consultation.

Further Study of Selective Withdrawal

Increasing mainstem water temperatures by means of selective withdrawal structures installed at Glen Canyon Dam offers the greatest potential for creating new spawning populations of humpback chub and other native fish in Grand Canyon. Selective withdrawal directly addresses the thermal constraints on recruitment and growth of endangered and other native fish not addressed by operational changes alone.

Prior to the dam, the water quality (including temperature) of the Colorado River was much different than today. Water temperatures varied seasonally, directly influenced by spring snowmelt and summer warming. Seasonal variations in temperatures ranged from 32 degrees Fahrenheit (°F) to 82 °F. Today, the cold water released from the dam varies only a few degrees year-round.

Water released from Glen Canyon Dam to produce hydroelectricity is withdrawn from the cold depths of Lake Powell at an elevation of 3470 feet—230 feet below the water surface when the reservoir is full (3700 feet). The river water temperature at Lees Ferry, 16 miles downstream, is nearly constant year-round and averages about 46 °F.

The nearly constant year-round release temperatures have resulted in conditions "not unlike those found in a well-balanced aquarium" (Carothers and Brown, 1991). Only a few species of aquatic organisms thrive under these conditions, but those few species are abundant. They account for biomass production far exceeding that in more diverse and species-rich environments. However, many native species require thermal changes at certain life-cycle stages and cannot reproduce in these constant temperature conditions.

Except for draining the reservoir, no operational method would prevent the continued release of cold water. Multilevel intake structures (a means of selective withdrawal) could be built at Glen Canyon Dam to provide seasonal variation in water temperature. A structure would be attached to each of the eight existing 15-foot-diameter penstocks to selectively withdraw warmer water from upper levels of the reservoir.

The structure would include a series of vertically stacked gates to enclose each penstock intake. Different configurations of gates could be opened to mix water of varying temperatures. Gate control would be automated, and adjustments would be made in relation to reservoir elevation, turbine operation, and water temperature.

Preliminary studies (Ferrari, 1988) indicated that multilevel intake structures on each of the eight existing penstocks could increase the downstream river temperature 5 to 18 °F above present conditions (river temperatures between 54 and 69 °F from May to October). This temperature increase is still 7 to 16 °F cooler than predam conditions during the summer months and is the warmest possible temperature (not necessarily the optimum temperature) for native fish or other resources. Withdrawal levels could be seasonally adjusted to meet ecological objectives, although this would involve complex factors.

Releasing warmer water during the spring and summer months could possibly raise river temperatures in some downstream reaches to a level that would support spawning by humpback chub and other native fish (Bureau of Reclamation, 1994a). However, increasing the temperature of river water may also create problems for species currently inhabiting the Colorado River below Glen Canyon Dam. The cold river temperatures may act as a barrier to the upstream establishment of non-native predatory fish from Lake Mead. Higher water temperatures may encourage the upstream migration of predatory fish, further endangering humpback chub and other native fish through increased predation or competition.

The cost of installing multilevel intake structures at Glen Canyon Dam has been estimated at $60 million. This estimate is based on actual costs for similar structures at Flaming Gorge Dam.

Reclamation would implement a selective withdrawal program and determine feasibility by aggressively pursuing and supporting research on the effects of multilevel intake structures at Glen Canyon Dam and would use the research results to make a firm decision on construction. FWS, in consultation with AGFD, would be responsible for recommending to Reclamation whether or not selective withdrawal should be implemented at Glen Canyon Dam. Reclamation would be responsible for design, NEPA compliance, permits, construction, operation, and maintenance.

Emergency Exception Criteria

Normal operations described under any alternative would be altered temporarily to respond to emergencies. NERC has established guidelines for the emergency operations of interconnected power systems. A number of these guidelines apply to Glen Canyon Dam operations (see attachment 6). These changes in operations would be of short duration (usually less than 4 hours) and would be the result of emergencies at the dam or within the interconnected electrical system. Examples of system emergencies include:

- Insufficient generating capacity
- Transmission system: overload, voltage control, and frequency
- System restoration
- Humanitarian situations (search and rescue)

A specific example of implementation of emergency exception criteria is the response to a magnitude 6.6 earthquake in the vicinity of Los Angeles on January 17, 1994. Damage to the Los Angeles transmission system caused a sequence of power surges and interruptions across most of the Western States. Glen Canyon Dam, responding more quickly than the thermal plants to changes in frequency and load, provided an additional 100 megawatts of power. As indicated by records for the USGS gauging station below the dam, the short-duration change in power generation caused a 4,340-cfs increase in 30 minutes (a stage increase of 1.6 feet) during a scheduled upramp. The change was undetectable at the Lees Ferry gauging station, where the maximum 30-minute river stage increase was about 3 inches.

Mitigation

All environmental mitigation has been incorporated into the alternatives identified for detailed analysis; no other mitigation elements are presently included. Future measures that could be considered as mitigation for the loss of power are described below.

Power Adjustments

The Grand Canyon Protection Act directs the Secretary of Energy to consult with other agencies and the public to identify economically and technically feasible methods of replacing any power generation that is lost through changed operations at Glen Canyon Dam. The Secretary of Energy must present a report of the findings and draft implementing legislation, if necessary, not later than 2 years after adoption of new operating criteria (ROD). That process should result in acquisition of permanent replacement power.

The manner in which Western markets energy and capacity from Glen Canyon Dam would differ for each alternative (see chapter IV, HYDROPOWER). Some basic options that exist to replace lost power are listed below:

- Purchase power from alternate sources
- Increase energy conservation
- Change transmission system capability
- Build new generating facilities

Some of these options may take 5 to 7 years to fully implement. Continuing use of the financial exception criteria allowed under interim operations is a potential short-term (5- to 7-year) mitigation measure. These financial exception criteria relate to Western's ability to demonstrate that unused generation capacity is available to meet firm (guaranteed) contract commitments at times when nonfirm (nonguaranteed) thermal energy is being used to meet those commitments. Under interim operating criteria, operational limits can be exceeded for financial reasons up to 3 percent of the time (22 hours) in any consecutive 30-day period, with no carryover.

Actually exceeding operating criteria for financial reasons is unlikely. While Western's customers have benefited from having financial exception criteria available during interim operations, Western has not had to exceed operating criteria for financial reasons.

Environmental resources such as fish and wildlife would be protected by avoiding use of financial exception criteria during specific periods of vulnerability (i.e., during breeding and nesting). If operations to avoid purchases of high-cost power were determined to be occurring too frequently or at inappropriate times, the Secretary of the Interior could suspend those operations and review the matter, making any necessary changes.

If financial exception criteria are part of the selected alternative, the availability of capacity and energy would be maintained, and costs to customers would be expected to increase at a slower rate.

Permits and Regulatory Approvals

No permits or regulatory approvals would be immediately necessary to implement any of the alternatives described in this document. Depending on the results of long-term monitoring and research under adaptive management, permits under sections 402 and 404 of the Clean Water Act may be needed in the future.

Implementing multilevel intake structures would require additional NEPA compliance, congressional authorization, and permits. A permit from the U.S. Army Corps of Engineers (Corps) under section 10 of the Rivers and Harbors Act and possibly section 404 of the Clean Water Act might be required, depending on the structure design and the amount of fill material used in construction. The Corps would make a decision on issuing a permit only after a public notice and public interest review. Supplementary NEPA documentation might be required, including a section 404(b)(1) alternatives analysis, if fill material is involved.

ALTERNATIVES CONSIDERED AND ELIMINATED FROM DETAILED STUDY

During the scoping process, including formulation of alternatives, various alternatives and concepts were considered. Some were determined not reasonable for detailed analysis in this EIS, as explained in this section.

Run-of-the-River Alternative

Many comments received during the scoping process expressed a desire that the dam be operated to mimic predam conditions in Grand Canyon.

The natural predam conditions of the Colorado River were characterized by dramatic seasonal fluctuations in flow, sediment, and temperature. Flows typically ranged from less than 3,000 cfs in late summer, fall, and winter to over 80,000 cfs in spring. The river usually was turbid, and peak sediment loads were carried by spring and late summer floods. Water temperatures ranged from near freezing in winter to more than 80 °F in late summer.

Steep sediment deposits were built annually during the sediment-laden spring floods. These deposits later tended to erode following the return to lower flows. Native vegetation existed in the old high water zone above the level of annual scour but was sparse to nonexistent on deposits influenced by seasonal fluctuations. Native plants and animals were well-adapted to this system of strong seasonal fluctuations.

Non-native species were introduced to Grand Canyon prior to dam construction. Warmwater non-native fish may have been introduced as early as the late 1800's. Tamarisk, a non-native plant that now dominates riparian vegetation, also was present predam. However, tamarisk and other vegetation were uncommon near the river where floodflows annually restructured sediment deposits. Lake Powell—formed behind the dam—now inundates all but 16 miles of Glen Canyon.

Glen Canyon Dam has replaced seasonal flow fluctuations with daily fluctuations that can range from 1,000 cfs to 31,500 cfs. Sediment is supplied only by downstream tributaries, and water temperatures are nearly constant year-round—averaging a cool 46 °F. Species and communities that were rare or nonexistent before the dam are now abundant: *Cladophora*, *Gammarus*, trout, bald eagles, peregrine falcons, and riparian vegetation and its wildlife in the new high water zone. Native and some species of non-native fish have declined.

The EIS team responded to scoping comments by formulating the Run-of-the-River Alternative. The objective of this alternative was to mimic, as nearly as possible, the natural predam conditions. This would be achieved through operational changes, sediment augmentation, and selective withdrawal.

The historic pattern of high spring flows and low fall and winter flows would be achieved by matching releases from the dam with inflows to Lake Powell. Spring releases would be limited to 48,000 cfs (combined capacity of powerplant and outlet works), unless the spillway could be used; then releases would equal inflow. Under these operating principles and based on predam inflows, flows in May could exceed 45,000 cfs about 40 percent of the time, and June flows could equal or exceed 45,000 cfs about 60 percent of the time. Low steady inflows and the resulting releases as low as 1,000 cfs would occur during late summer and winter.

The frequency of high flows needed to simulate predam conditions would scour most of the sediment along the river corridor in Grand Canyon. Tributaries below Glen Canyon Dam cannot supply large amounts of sediment on an annual basis, so the sediment would not be replaced naturally. The scouring of sediment from Grand Canyon would damage environmental, recreational, and cultural resources in the canyon. Postdam sediment losses have been reduced by regulating the frequency of high-flow releases from Glen Canyon Dam.

For these reasons, the Run-of-the-River Alternative would require massive sediment augmentation (1 to 10 million tons annually) in order to replenish sediments transported out of the system. Several technical issues concerning sediment augmentation were considered, such as sediment quantity and size (sand, silt, clay), source, and type of delivery system. Potential sediment delivery systems considered included a barge and truck operation and a sediment slurry pipeline to Lees Ferry. Sediment would be dredged from a remote source and then continually transported and deposited in the Colorado River. The river would then carry the sediment downstream for deposit in eddies and main channel pools.

Any sediment source would have to be renewable in order to indefinitely sustain the sandbars in Grand Canyon under the suggested water release regime. Therefore, sediment deltas of Lakes Powell and Mead were considered as possible sources for sediment augmentation. The areas of Lake Powell considered as possible sources of sediment were the upstream delta along the mainstem (Cataract Canyon), the San Juan River, and the Dirty Devil River.

To more closely approximate predam seasonal patterns, some type of temperature modification was needed in the Run-of-the-River Alternative. To increase river water temperature, multilevel intake structures would be placed on the dam penstocks to draw warmer water from near the reservoir surface for release downstream. This approach would raise downstream water temperatures 5 to 18 °F above current conditions during spring and summer.

Evaluation of Alternative

Evaluation of the Run-of-the-River Alternative focused primarily on flows/sediment, environmental concerns, and compact and treaty requirements.

Flows/Sediment. Sediment augmentation would be required to maintain a sediment balance in the river system when high releases are frequent. Without sediment augmentation, the Run-of-the-River Alternative would eventually erode most of the sediment from Grand Canyon—damaging or destroying the canyon's environmental, recreational, and cultural resources.

A slurry pipeline would likely take at least 15 to 20 years to implement. This timeframe includes necessary research and data collection, NEPA compliance, design, Federal permitting, congressional authorization, land purchase/ easements, implementing mitigation procedures, and construction.

The cost of building a slurry pipeline was estimated at $400,000 per mile. For a completed pipeline to the river deltas of the San Juan, Dirty Devil, or mainstem (Cataract Canyon), costs were estimated at $50, $80, and $85 million, respectively. Operational costs could be $10 million per year. Other means of sediment transport (barging and trucking) would be more expensive than a slurry pipeline.

Environmental Concerns. Any overland route for sediment transport to the Colorado River below Glen Canyon Dam would cross more than 100 miles of high-desert canyon landscape to reach the nearest renewable source of sediment. Construction would cause adverse environmental impacts to fragile resources. Cultural and archeological impacts on tribal lands would be significant and would require additional compliance with the National Historic Preservation Act and other cultural resource legislation. A submerged pipeline in Lake Powell would affect recreation during construction and would require an overland route to Lees Ferry.

Sediment would be augmented just below Lees Ferry so as not to increase turbidity in the Glen Canyon reach, which would adversely affect the trout fishery. The high spring flows would scour most of the sand deposits from the river upstream from Lees Ferry.

Low flows during the winter spawning season would reduce habitat for rainbow trout, and extended low flows at any time would adversely affect the *Cladophora-Gammarus* segment of the aquatic food chain throughout Grand Canyon. Important unanswered questions exist concerning the types and amounts of contaminants that may be found in some of the sediment sources identified above and their effects on resources if added to the aquatic system below the dam.

Lastly, modification of water temperature in the Colorado River below Glen Canyon Dam presents both opportunities for enhanced management of some resources and risks associated with unknown responses. Higher water temperature may benefit humpback chub and other native fish but also may improve habitat conditions for competing non-native species and permit an invasion of striped bass from Lake Mead. The current water temperature is below the optimum for rainbow trout growth, but it is unknown how the alga, *Cladophora,* and the shrimp-like amphipod, *Gammarus*—which trout depend on—would respond to higher temperatures.

Compact and Treaty Requirements. Releases from Glen Canyon Dam under this alternative would not meet the annual water release pattern requirements of the "Law of the River," especially the Colorado River Compact, the Colorado River Basin Project Act, the Long-Range Operating Criteria, and the treaty with Mexico. Therefore, this alternative would violate existing laws.

Under the Run-of-the-River Alternative, releases from the dam could only match high spring inflows when Lake Powell was full and the spillways could be used. Because of the way the dam is designed, the spillways cannot be used unless the reservoir is nearly full. Without using the spillways, releases cannot exceed 48,200 cfs. Inflows to Lake Powell in June typically exceed 45,000 cfs, and the excess would have to be stored in the reservoir. Lake Powell could be expected to fill and spill at an average frequency of 1 out of every 4 years under this alternative.

Conclusions

Restricting releases to reservoir inflow during prolonged drought periods would prevent Glen Canyon Dam from meeting its statutory purposes. Requirements under the Colorado River Compact and treaty with Mexico could not be met.

The natural environment along the river corridor has been forever altered with the introduction of non-native species and the construction of Glen Canyon Dam. Under this alternative, the river would be converted into a system very different from existing conditions. Resources associated with the aquatic food chain would be disrupted—*Cladophora, Gammarus*, aquatic insects, trout, swallows, bats, bald eagles, and peregrine falcons.

Most of these impacts would be associated with the massive addition of sediment needed to prevent the net loss of sediment and sediment-dependent resources. Sediment augmentation would cause significant impacts to water quality—most notably increased turbidity. The chemistry of various sediment sources and corresponding impacts to Grand Canyon water quality and aquatic resources are unknown.

The need for sediment augmentation has not been demonstrated under alternatives with reduced daily flow fluctuations. For example, sandbars still exist in Grand Canyon and appear to be stable under the interim operating criteria.

A sediment augmentation delivery system would cause environmental damage along the route during construction and operation and would be expensive to build and maintain.

Some people consider sediment augmentation the ultimate solution for Grand Canyon because a portion of the natural sediment supply could be restored and the life of Lake Powell could be extended (there would be a corresponding decrease in the life of Lake Mead). However, others doubt the wisdom of using a major construction project to solve the environmental problems of a previous construction project. In either case, sediment augmentation would take a long time to implement—perhaps 15 to 20 years—and a plan to operate Glen Canyon Dam would still be needed in the interim.

Sediment augmentation would require data collection; research and analysis; an EIS addressing alternate sediment sources and delivery systems; congressional authorization and funding; Federal, State, and tribal permits; land purchases and easements; and construction. A project of this magnitude is beyond the scope of dam operations and would be better addressed in a separate NEPA document.

Without sediment augmentation, the volumes of clear-water releases defined in this alternative would eventually eliminate most sediment deposits along the Colorado River in Glen and Grand Canyons. This loss would affect recreational opportunities, cultural resources, backwaters, marshes, and riparian vegetation. Mitigating these impacts by reducing seasonally high flows creates a flow regime incorporated into the Seasonally Adjusted Steady Flow Alternative.

In conclusion, the EIS team recognized the desire of some to return riverflows to a more historic (predam) pattern. A return to a seasonal streamflow pattern emulating the magnitude of historic spring flows would, however, be very destructive to downstream resources unless a large-scale, long-term sediment augmentation program were added. This program would have significant impacts—all of which are not yet known. If sediment augmentation is desired in the future, this action should be the subject of a separate EIS. The Run-of-the-River Alternative was therefore eliminated from further consideration in this document.

Historic Pattern Alternative

Comments received during the scoping process indicated that many respondents wished to alter dam releases to return to predam flow patterns. The Historic Pattern Alternative attempted to follow predam water flow patterns more closely while still managing flows within current powerplant capacity.

This alternative was a modification of the Run-of-the-River Alternative. Minimum annual releases of 8.23 maf would be met, and all scheduled releases would be within powerplant capacity. Flows would be steady each month while following a seasonal pattern of higher spring/summer and lower fall/winter flows. Maximum flows would be limited to 33,200 cfs, and minimum flows would be determined by the forecasted annual release remaining after high spring/summer flows were allocated. The Historic Pattern Alternative also included a sediment slurry pipeline and multilevel intake structures for the reasons discussed under the Run-of-the-River Alternative.

Evaluation of Alternative

Although the high flows under the Historic Pattern Alternative would be of less magnitude and perhaps of shorter duration than under the Run-of-the-River Alternative, sediment augmentation would still be required to prevent long-term adverse impacts to downstream resources. Without sediment augmentation, the sediment resources along the Colorado River would be more subject to erosion under the Historic Pattern Alternative than under any of the steady or fluctuating flow alternatives, including the No Action Alternative. The Historic Pattern Alternative was not expected to conflict with the "Law of the River."

Conclusions

This alternative was eliminated from detailed study for most of the reasons given for the Run-of-the-River Alternative. Specifically, sediment augmentation would cause an increase in turbidity and disrupt the aquatic food chain below Lees Ferry, and high and low flows would adversely affect resources above Lees Ferry. Other potentially adverse impacts are unknown. Sediment augmentation would require 15 to 20 years to implement, and a plan to operate the dam in the interim still would be needed.

Without sediment augmentation, the flows under this alternative would cause more erosion to sediment deposits below Glen Canyon Dam than other steady or fluctuating flow alternatives, including no action operations. Mitigating these impacts by reducing seasonally high flows creates a flow regime incorporated into the Seasonally Adjusted Steady Flow Alternative. For these reasons, the Historic Pattern Alternative was eliminated from further consideration in this document.

Reregulated Flow Alternative

The EIS team responded to scoping comments requesting full use of Glen Canyon Dam Powerplant's generating capacity by developing the Reregulated Flow Alternative. The objective of this alternative was to initiate operational changes to fully use the powerplant's generating capacity (flows of 33,200 cfs) while reducing, to the extent possible, existing adverse impacts to downstream resources by constructing a reregulation dam.

Releases from Glen Canyon Dam under this alternative would be similar to those described under the No Action Alternative, with maximum flows increased to 33,200 cfs and minimum flows of no less than 1,000 cfs year-round. Annual and monthly releases would be based on the following factors: meeting water deliveries to the Lower Basin States, maintaining conservation storage in Lake Powell, avoiding anticipated spills, balancing storage between Lakes Powell and Mead, and seasonal power demand patterns. Daily releases would be patterned to meet power demand within the limits of the required monthly release volume. Ramp rates would be constrained only by physical limitations of the powerplant.

An increase in the magnitude of daily fluctuations would cause additional impacts to downstream resources at levels above those documented for the No Action Alternative at 31,500 cfs. To reduce new and existing impacts, a reregulation dam would be constructed approximately one-half mile upstream of the gauge at Lees Ferry to provide steady flows downstream of the reregulation dam. The top of the dam would extend about 20 feet above the downstream water surface.

Flows below the reregulation dam would follow a daily pattern of steady flows but would be adjusted daily and monthly. Minimum steady flows would be about 8,000 cfs, and maximums would be dictated by the monthly and daily volume to be released. Downstream of the reregulation dam, changes in river stage between weekdays and weekend days would likely occur because the average daily release may be lower on a weekend day than on a weekday; however, the transition between flows would be gradual. Effects of ramping would be virtually unnoticeable below the reregulation dam.

Between Glen Canyon Dam and the reregulation dam (Glen Canyon reach), the river would be converted to a fluctuating reservoir storing water during the day for release later at night. Minimum water elevation at the upstream face of the reregulating dam would increase 4 feet, and the water level would fluctuate up to 17 feet daily. This fluctuating reservoir would act as the damper to accept the fluctuating releases of Glen Canyon Dam and would convert them to nearly steady releases below the reregulation dam.

Evaluation of Alternative

The Reregulated Flow Alternative would provide complete flexibility in power operations at Glen Canyon Dam while providing a mechanism for protecting physical and biological resources downstream from Lees Ferry (260 miles). However, the river reach between Glen Canyon Dam and the reregulation dam (15 miles) would be altered by increased fluctuations.

Flows and Sediment Resources. Steady flows below a reregulation dam would virtually eliminate rapid changes in flows and would reduce the capability of the river to transport sediment. Under these conditions, natural input of sediments from tributaries (Paria and Little Colorado Rivers) would allow sediment to accumulate in the river corridor at relatively low elevations.

Fluctuations in flow above the reregulation dam would be considerably higher than under historic operations. In the Glen Canyon reach, sediment exposed to these higher release fluctuations would continue to be lost. Further, because river stages would be from 4 feet to 20 feet higher in elevation, sediment deposited above historic normal operational ranges would be subject to fluctuations and loss. Because this reach lacks a source of sediment input, these operations eventually would eliminate most of the sand and fine-grained sediment from sandbars and banks in the Glen Canyon reach.

Riparian and Terrestrial Resources. Stabilized flows downstream from the reregulation dam would promote further development of riparian resources on stabilized sandbars in Grand Canyon. Terrestrial wildlife linked to riparian resources would benefit from the stabilized riparian corridor.

The AGFD categorizes the riparian habitat found in the Glen Canyon reach as Resource Category I habitat (of the highest value to wildlife) and recommends that all potential losses of existing habitat values be prevented. Riparian habitat associated with perennial streams in Arizona is considered unique and irreplaceable on a statewide basis.

The loss of sandbars through inundation in the reach above the reregulation dam would result in the direct loss of riparian resources. Riparian vegetation near the reregulation dam would be immediately inundated, and virtually all riparian resources in this reach would be eliminated as sandbars eroded due to rapid fluctuations in water level.

Aquatic Resources. The placement of the reregulation dam would not directly disturb habitat used by the endangered humpback chub. Reregulated flow to the river reaches below the LCR could stabilize backwaters and promote warming that would provide rearing habitat for larval or juvenile chub. River temperatures would remain cold, thus limiting the movement of larval humpback chub out of the LCR. Stabilized flows would not guarantee that backwaters would be maintained through time. As backwaters developed into riparian areas over time, they would eventually lose their value as fish-rearing habitat. Reregulated flows would not create additional spawning habitat for humpback chub in the main channel nor would they encourage establishment of new spawning populations in tributaries.

The aquatic system above the reregulation dam would be altered. Accelerated sandbar erosion caused by increased fluctuations—combined with lake-like conditions in the reach above the reregulation dam—would favor planktonic algal forms, which could decrease water clarity. Changes in water clarity, combined with weekend minimum stages, could reduce the zone occupied by the alga, *Cladophora*. Reduced *Cladophora* and/or reductions in its transport out of the reregulating reservoir could result in the entire food chain being restructured throughout the river in Grand Canyon.

Restructuring the food chain above and below the reregulation dam would affect the existing trout fishery. This resource would change from a "stream" to a "lake" fishery above the reregulation structure, with very different management needs and expectations. Natural reproduction would be reduced. Impacts to *Cladophora* and the algal/invertebrate community associated with it would reduce the probability of maintaining a blue ribbon trout fishery within the Glen Canyon reach. See chapter III for more information concerning fish needs.

Cultural Resources. More than 40 cultural sites have been documented within the Glen Canyon reach. In addition, two locations currently under evaluation could be Hopi spiritual sites. Greater fluctuations would increase the erosion affecting these sites. Some impacts to cultural sites could be mitigated by collecting data during excavation, but impacts to others cannot be mitigated because of their complexity or traditional nature. If these sites are determined to be sacred to Native Americans, by their very nature they cannot be moved, transferred, or excavated.

The reregulation dam would be built within the historic district of Glen Canyon National Recreation Area. Increased beach erosion and the inundation of additional areas of the Glen Canyon reach would affect the cultural heritage associated with the last remaining miles of Glen Canyon. This National Register Historic District contains one individually listed property, the Charles H. Spencer Steamboat, downstream from the potential damsite. Activities that may impact sites listed on the *National Register of Historic Places*, especially those that would alter the setting that justified registration, are considered adverse effects.

Recreation. White-water boating would not be inhibited by the near-steady flows below a reregulation dam; steady flows above 8,000 cfs are considered desirable conditions. However, recreation above a reregulation dam would change dramatically. The Glen Canyon reach typically is used by day rafters and fishermen. Under the Reregulated Flow Alternative, access to this reach was an unresolved issue. However, the type of access and the recreational fishery undoubtedly would change.

Safety would be a major concern for those using the reregulating reservoir. A policy decision on safety would be required from the NPS. If boating were permitted, a ramp would provide access upstream from the reregulation dam. Sustained high flows above powerplant capacity would overtop the reregulation dam spillway. Therefore, boat launching or operation near the reregulation dam under high flow conditions would be dangerous. Recreational use of this segment of Glen Canyon would likely be prevented for extended periods. Such closures would have exceeded 24 months as a result of the 1983-86 high flows.

Economics. Construction cost of a reregulating dam is estimated at $60 to $110 million. A reregulation dam would permit the powerplant to operate at maximum capacity whenever enough water was available (Lake Powell elevation greater than 3641 feet) and electrical demand was high. Estimates show that, under these criteria, the powerplant would operate at maximum capacity about 25 days per year (7 percent of the time) for less than 4 hours at a time.

Existing Legislation. The Grand Canyon Protection Act directs the Secretary to operate Glen Canyon Dam

> *. . . and exercise other authorities under existing law in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established . . .*

The 1916 act establishing the National Park Service defined those purposes generally as being

> *. . . to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.*

Section 3 of the Colorado River Storage Project Act (1956) states: "It is the intention of Congress that no dam or reservoir constructed under the authorization of this Act shall be within any national park or monument." Congress declared in 1970 and reemphasized in 1978 that all National Park Service areas, including Glen Canyon National Recreational Area, are interrelated and part of one national park system.

Public Acceptance. Planning and constructing a reregulating dam would be guided by the Federal Government's *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (Water Resources Council, 1983) that govern all implementation studies. These principles and guidelines apply the four tests of completeness, effectiveness, efficiency, and acceptability to all project alternatives that are considered reasonable. Although some segments of the public would find a reregulation dam acceptable, diverse groups have expressed strong opposition to placing a dam in the last remaining reach of the Colorado River in Glen Canyon.

Administrative Clearance. A reregulation dam would take at least 5 to 15 years to construct after the ROD. This estimate includes such activities as research and data collection, additional NEPA compliance, design, Federal permitting, consultation with the Arizona State Historic Preservation Officer and the Advisory Council on Historic Preservation, excavation of cultural sites, consultation under the Endangered Species Act, congressional authorization, implementation of mitigation procedures, and construction. Construction impacts would be irreversible.

Conclusions

Construction of a reregulation dam in Glen Canyon National Recreation Area would require a change in existing law. While most downstream resources would experience improved conditions over the No Action Alternative, resources in the Glen Canyon reach would experience negative impacts under the Reregulated Flow Alternative.

Resources in the Glen Canyon reach that would be adversely impacted include sandbars, riparian vegetation and associated terrestrial wildlife, *Cladophora* and associated algal and invertebrate communities, a regionally important trout fishery, recreation potential, Native American cultural and sacred sites, and archeological and historic areas/sites. Impacts to the *Cladophora*-based aquatic food chain could have effects throughout Grand Canyon.

Most of these impacts would result from the greater frequency and magnitude of fluctuations behind the reregulating dam constructed to protect downstream resources from those same fluctuations. A reregulating dam would require $60 to $110 million to construct and 5 to 15 years to implement without any opposition.

Impacts in the Glen Canyon reach could be mitigated by reducing the frequency and magnitude of daily river fluctuations. However, without maximum fluctuations, there would be no need for a reregulation dam. Reduced fluctuations and elimination of the reregulation dam create conditions identical to those evaluated under other fluctuating flow alternatives, including no action.

In summary, predicted impacts to resources, required changes in existing law, acceptability problems under the principles and guidelines, and the scrutiny required under section 404 of the Clean Water Act combine to render this alternative unreasonable at this time.

Concepts Eliminated From Detailed Study

Some comments received during the scoping process suggested concepts that were not formulated into detailed alternatives. A short discussion of those concepts follows. Although sand pumping and beach protection were eliminated from detailed study in this EIS, both could be considered during long-term monitoring under adaptive management.

Sand Pumping

Pumping sand from the river channel to rebuild eroded sandbars on a systemwide basis currently is not necessary and may not be in the future. Also, such an operation is not compatible with NPS management policies for reasons of visitor use and potential wilderness designation. In the future, NPS might decide to consider sand pumping on a site-specific basis, if needed. If so, NPS would be responsible for obtaining any required permits and NEPA compliance.

Description of Concept. Sandbars could be built by pumping sand from the river channel to a nearby site during low or normal flow. This could be done at specific locations identified by NPS to protect the base of slopes containing prehistoric or historic resources or to enhance sites for recreational purposes.

This action could be taken only where channel sand deposits are available. A source of river channel sand nearest each selected site would be located. Small portable pumping equipment would be transported downstream by raft, and a temporary, small barrier or berm to contain the pumped sand would be constructed on a site. A sand-water mixture would be pumped into the contained area. Water would then drain back to the river through the barrier or underlying sandbar, and the pumped sand would remain. The barrier would be removed at the end of the pumping operation. The newly deposited sand would form a more natural slope after being reworked by wind and water.

The sand pumping operation would most likely take place during January or February when recreation use is lowest. This concept would be flexible because both the number of beaches targeted and the frequency of sand pumping could be varied, assuming channel-stored sand is available.

Cost estimates for pumping river bottom sand range from $30,000 to $150,000 per year.

Evaluation of Concept. Grand Canyon sandbars are scarcest in narrow reaches. However, sand pumping in these reaches would be difficult because of strong river currents and may not be possible due to scarcity of riverbed sand.

If long-term net erosion of low elevation sandbars were to occur, it would likely be due to a shortage of sand in the river channel, and sand pumping would not be a feasible method of sandbar restoration because of lack of supply. Results from the long-term monitoring program may identify sites where sand pumping should be considered. The feasibility of sand pumping would have to be evaluated on a case-by-case basis.

Beach management by sand pumping would be a minor project involving only a few beaches but would require a permit from the Corps under section 10 of the Rivers and Harbors Act and section 404 of the Clean Water Act. A formal application must be submitted to the Corps by the agency proposing such work. A separate NEPA document also would be required, which would establish a site-specific project purpose and include a section 404(b)(1) analysis to identify the least-damaging practicable alternative in terms of cost, logistics, and available technology.

Beach Protection

Beach protection on a systemwide basis is not currently necessary and likely will not be needed. NPS will determine if beach protection at certain sites is feasible and appropriate and, if so, obtain any required permits and NEPA compliance.

Description of Concept. Rock jetties or riprap lining (layer of rock) could be placed to protect or rehabilitate existing sandbars. A jetty would be used to divert high velocity flow away from a sandbar and create a small eddy on the downstream side of the structure. Riprap lining of the channel bank would help prevent sandbar erosion by high water velocities and recreational activity. Either of these protection measures would work well in conjunction with a sand pumping operation.

All structures would consist of native rock and vegetation and would be designed to blend with the natural environment. No steel, wires, or concrete would be used. Rock would be obtained from nearby tributary debris fans and not from talus slopes or canyon walls. All rock would be placed by hand or with small mechanized equipment. Because of logistical difficulties, only sites that are within a few hundred yards of a debris fan could be protected this way.

Any necessary equipment and personnel would be transported by raft from Lees Ferry. These structures would require a maintenance program with access by raft. Cost estimates for beach protection have not been determined.

Evaluation of Concept. Grand Canyon sandbars are scarcest in narrow reaches. However, beach protection in these reaches would be difficult due to strong river currents and may not be possible due to the scarcity of nearby debris fans (source of rock).

Due to the unique logistical problems in Grand Canyon, sandbars could be protected with riprap only above the low river stage. High water velocities could scour the sandbar below the riprap and cause the entire beachface to fail. Sandbar erosion due to a rapid drop in river stage during fluctuating flows has been documented (Beus and Avery, 1992). However, riprap would not be effective against this type of erosion.

Results from the long-term monitoring program may identify sites where beach protection should be considered. The feasibility of beach protection would have to be evaluated on a case-by-case basis.

Beach management by bank protection would be a minor project involving only a few beaches but would require a permit from the Corps under section 10 of the Rivers and Harbors Act and section 404 of the Clean Water Act. A formal application must be submitted to the Corps by the agency proposing such work. A separate NEPA document would be required that would establish a site-specific project purpose and include a section 404(b)(1) analysis to identify the least damaging practicable alternative in terms of cost, logistics, and available technology.

Remove Glen Canyon Dam

Removal of the dam is considered unreasonable in view of:

- The many established beneficial uses that it now serves
- The legal framework ("Law of the River") that now exists, including the Grand Canyon Protection Act of 1992
- The investment that the dam represents
- The adverse social, economic, and other impacts to the existing human environment that would result from its removal

Most importantly, Reclamation was directed by the Secretary to evaluate alternative operations for Glen Canyon Dam. The concept of removal is an alternative to operating the dam and, thus, does not address dam operations. Since dam removal is outside the scope of dam operations, it violates the Secretary's charge to Reclamation. As a result, this concept was eliminated from further study.

Move Hydropower Peaking From Glen Canyon Dam to Hoover Dam

Both Glen Canyon and Hoover Powerplants already are operated as hydroelectric power peaking plants. No excess capacity or energy is available at Hoover to substitute for reduced peaking at Glen Canyon, as all of the capacity and energy at Hoover is allocated by existing contracts.

It has been suggested that more units could be added at Hoover to increase capacity and to supply the peaking that now occurs at Glen Canyon. However, Hoover modification is already being considered by the Arizona Power Authority and the Colorado River Commission of Nevada to augment their peaking needs. Therefore, power produced at Hoover may not be available for use in the area served by Glen Canyon power.

It may be possible in the future to apply additional computer technology on a regional or system basis to refine and enhance the efficiency of the power network, including Glen Canyon and Hoover Powerplants. This could facilitate some peaking and spinning reserve adjustments between the two projects.

SUMMARY COMPARISON OF ALTERNATIVES AND IMPACTS

Table II-7, presented at the end of this section, summarizes the impacts of the alternatives considered in detail on the affected environment. Impacts of the Maximum Powerplant Capacity and High Fluctuating Flow Alternatives would be very similar to those of the No Action Alternative.

Impacts under the Moderate and Modified Low Fluctuating Flow and Seasonally Adjusted Steady Flow Alternatives would be similar for most resources (because they include habitat maintenance flows) except hydropower. The habitat maintenance flows of these three alternatives would provide some ecosystem variability that was characteristic of the predam environment.

Impacts under the Interim Low Fluctuating Flow and Existing Monthly Volume and Year-Round Steady Flow Alternatives would be similar for most downstream resources and result in a relatively static environment.

The impacts on each of the affected resources are described in more detail in "Chapter IV, Environmental Consequences." These resources include: water, sediment, fish, vegetation, wildlife and habitat, endangered and other special status species, cultural resources, air quality, recreation, hydropower, and non-use value.

Resource Management Objectives

Federal, State, and Tribal Governments develop management objectives to define the desired condition of specific resources. The attainment or nonattainment of these objectives drive the implementation of management actions intended to maintain or reestablish the resource condition. In some cases, objectives must be reevaluated if they are not achieved.

As outlined in the Grand Canyon Protection Act of 1992, the actions considered in this EIS are intended to protect and mitigate adverse impacts to and improve the natural and cultural resource values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established. Many resources in Glen and Grand Canyons developed in response to conditions created by the dam. Reasonable objectives, developed by the management agencies, are goals for future management of these resources and provide meaning to the terms "protect," "mitigate," and "improve."

Reclamation, NPS, FWS, Western, AGFD, Hualapai Tribe, and Navajo Nation have management responsibilities associated with Glen and Grand Canyons and have developed resource management objectives.

The agency resource management objectives and the potential for the alternatives to meet those objectives are assessed below. Attainment of objectives for all resources will require complex interagency planning and management. Some issues would remain unresolved under any alternative.

WATER: Reclamation's water management objectives are to use Colorado River Storage Project (CRSP) reservoirs for the statutory purposes of flood control, river regulation, beneficial consumptive uses, water quality control, enhancement of fish and wildlife, other environmental factors, and power production. This is to be accomplished consistent with other applicable Federal laws, the Mexican Water Treaty, interstate compacts, and decrees.

The Navajo Nation seeks to ensure that dam operations will not affect existing or future water rights or the use of those rights.

NPS objectives are for releases that have a degree of variability to sustain sediment deposits and promote a dynamic ecosystem. Water released from the dam should meet or exceed State of Arizona standards for full-body contact use.

The Hualapai Tribe's objective for water releases is to establish a flow pattern that maintains long-term sustainable and balanced multiple use of its resources which include: cultural resources, fish, wildlife, vegetation, water supply and quality, and recreation enterprises.

Assessment: All of the alternatives would likely accomplish Reclamation objectives for CRSP reservoirs.

Raising the height of the spillway gates to reduce flood frequency would meet Navajo Nation objectives. The other flood frequency reduction measure (increasing exclusive flood control space) would decrease Upper Basin yield.

NPS and Hualapai objectives would be accomplished under the Moderate Fluctuating, Modified Low Fluctuating, and Seasonally Adjusted Steady Flow Alternatives. Water quality objectives would likely be attained under all alternatives.

SEDIMENT: NPS, Hualapai, and Navajo seek to maintain a long-term balance of river-stored sediment and the entire range of predam sediment deposits—including an annually flooded bare-sand active zone, a less frequently flooded vegetation zone, and predam terraces. They prefer a diversity of dynamic, higher-elevation sediment deposits over stable, low elevation deposits.

Some actions taken to benefit Grand Canyon may have negative consequences in the Glen Canyon reach, and such consequences must be considered.

Assessment: All management objectives for sediment (except high terraces) in Grand Canyon would be accomplished under the Moderate and Modified Low Fluctuating Flow Alternatives and the Seasonally Adjusted Steady Flow Alternative. These alternatives provide the greatest cycles of deposition and erosion and maintain sandbars at the highest elevations, since daily release fluctuations would be restricted and seasonal variability would be added—primarily through habitat maintenance flows. However, high terraces would continue to erode under any alternative. Glen Canyon sediment would be subject to long-term net erosion under any alternative.

FISH: NPS, Hualapai, and AGFD objectives for native fish are to ensure viable populations in Grand Canyon. The Hualapai seek to completely eliminate carp from Glen and Grand Canyons. FWS objectives for native fish are to closely mimic the natural, predam ecosystem process under which native fish evolved.

NPS, AGFD, Hualapai, and Navajo objectives for the trout fishery are to provide a recreational resource while maintaining and recovering native fish in Grand Canyon. In the Glen Canyon reach, their objective is to encourage natural reproduction, survival, and growth of trout to blue ribbon quality sizes. In Grand Canyon, the objective is to sustain a wild trout fishery.

Assessment: To assure future accomplishment of agency objectives for native fish, additional research is needed on native and non-native fish interaction, the feasibility of selective withdrawal, the potential for reintroduction of extirpated native fish, and potential for eliminating carp.

Achievement of objectives for native fish vary by species. None of the alternatives appear to increase spawning habitat for native fish in the mainstem. Selective withdrawal may be required to allow warmer releases. Reproduction and recruitment of razorback sucker in Grand Canyon is virtually unknown; it is unlikely that any of the alternatives in and of themselves will reverse this trend.

Flannelmouth sucker appear to be favored by those alternatives that create or maintain rearing habitats in the mainstem (i.e., Modified Low Fluctuating and Seasonally Adjusted Steady Flow Alternatives).

All steady flow alternatives and the Modified Low and Interim Low Fluctuating Flow Alternatives would likely meet AGFD, NPS, Hualapai, and Navajo objectives for the trout fishery and its food base.

VEGETATION: NPS, Hualapai, and Navajo objectives for vegetation in the river corridor are to maintain a dynamic ecosystem made up of diverse groups of native, riparian plant species at different stages of succession and at different elevations above the water line. Emergent marsh vegetation should be sustained as a functioning, dynamic resource providing wildlife habitat that changes in location and extent in response to flow and sedimentation processes.

The Hualapai Tribe seeks to remove non-native vegetation, as necessary, to maintain campsites.

Assessment: Habitat maintenance flows, which are components of the Moderate Fluctuating, Modified Low Fluctuating, and Seasonally Adjusted Steady Flow Alternatives, provide the greatest potential for accomplishing the NPS, Hualapai, and Navajo objective for sustaining a dynamic ecosystem. Other alternatives result in system stability or eventual loss of ecosystem components. Because of the regulated flows, it would be difficult under any alternative to achieve the NPS objective of maintaining dynamic marshes. However, alternatives with habitat maintenance flows and variable water releases among years should maintain some marsh dynamics.

WILDLIFE AND HABITAT: NPS, Hualapai, and Navajo objectives are to provide for diversity of wildlife species, giving priority to native species and associated natural processes.

Assessment: Objectives for vegetation—and thus aquatic and terrestrial habitat—would be best met under the Moderate and Modified Low Fluctuating Flow Alternatives and the Seasonally Adjusted Steady Flow Alternative, therefore providing the greatest potential for accomplishing wildlife objectives.

ENDANGERED AND OTHER SPECIAL STATUS SPECIES: NPS, FWS, AGFD, Hualapai Tribe, and Navajo Nation objectives are to monitor, protect, and recover populations of endangered species, candidate species, and State-listed species.

Recovery plans developed for threatened and endangered species specify FWS and AGFD objectives. Final recovery plans have been approved for the bald eagle, peregrine falcon, and humpback chub; a recovery plan for the razorback sucker is being developed. FWS and Navajo Nation objectives specific to the humpback chub and other native fish are to protect the LCR and restore mainstem populations.

Assessment: It may not be possible to accomplish these objectives for some native fish under any of the alternatives without adopting other measures such as selective withdrawal. Objectives for terrestrial species, including bald eagle, peregrine falcon, and willow flycatcher, would likely be met by sustaining the processes needed to accomplish sediment and ecosystem objectives (i.e., Moderate Fluctuating, Modified Low Fluctuating, and Seasonally Adjusted Steady Flow Alternatives). However, dam operations alone cannot meet some objectives for endangered fish over the long term.

The entire Grand Canyon humpback chub population is in jeopardy, partly because of the limited distribution of the fish. Establishment of a second spawning population of the humpback chub is an express objective of AGFD, FWS, Hualapai Tribe, and Reclamation. This objective may be met by establishing a spawning population either in another tributary or in the mainstem, which is a common element under all restricted fluctuating and steady flow alternatives. Humpback chub would appear to be able to maintain a viable population under all alternatives but only because the LCR provides spawning habitat.

FWS believes that their management objectives can best be accomplished under the Seasonally Adjusted Steady Flow Alternative during low release years (see attachment 4).

CULTURAL RESOURCES: NPS and cooperating tribe objectives are to maintain the integrity of all cultural resources within the river corridor, with site preservation as the optimal condition, and to maintain biological and spiritual resources important in preserving Native American values.

For the cooperating tribes, preserving traditional cultural properties—including access to cultural properties and perpetuation of cultural practices within Glen and Grand Canyons—is the highest priority.

Assessment: Moderate Fluctuating, Modified Low Fluctuating, and Seasonally Adjusted Steady Flow Alternatives would contribute most toward preserving sites in place. However, management actions other than dam operations may be required to meet NPS and cooperating tribe objectives over the long term.

The same three alternatives would most likely preserve and maintain biological and spiritual resources important to Native Americans. Objectives for biological resources would not be as well met under the other steady flow alternatives and Interim Low Fluctuating Flow Alternative. Cultural resource objectives, in general, would not be met under the unrestricted fluctuating flows or the High Fluctuating Flow Alternative.

RECREATION: NPS, Hualapai, and Navajo objectives are to provide opportunities for recreational experiences along the river corridor that do not diminish natural or cultural resource values and to protect and preserve environmental and wilderness conditions that contribute to quality recreation experiences. Flows should allow navigation by white-water boats in Grand Canyon and power boats in Glen Canyon. In Glen Canyon, AGFD and NPS seek to maintain a blue ribbon angling opportunity and to provide safe boating and access for boaters, waders, and campers. AGFD seeks to provide access for hunting waterfowl in this reach.

The Hualapai Tribe also promotes motorized white-water boating, hunting, camping, and sightseeing in lower Grand Canyon. The Navajo Nation also seeks to provide recreational opportunities for Navajo people and to support and enhance recreation and tourism industries in northern Arizona.

Assessment: The steady flow alternatives would offer the most immediate benefits for recreation activities and attributes. However, the Moderate Fluctuating, Modified Low Fluctuating, and Seasonally Adjusted Steady Flow Alternatives would best meet the long-term recreation objectives of NPS, Hualapai, and Navajo.

All alternatives except the Maximum Powerplant Capacity Alternative would improve boating access and navigation over no action.

AGFD and Hualapai objectives for fishing, hunting, and safety would be realized most under the steady flow alternatives and, to a somewhat lesser degree, under the Modified Low and Interim Low Fluctuating Flow Alternatives.

HYDROPOWER: Western's objective is to serve the public interest by marketing and delivering the greatest amount of long-term firm power and energy from Glen Canyon Dam Powerplant while striving to protect and enhance environmental values both downstream of Glen Canyon Dam and throughout the marketing area.

Assessment: Western's objective is most readily accomplished under the Moderate Fluctuating Flow Alternative. The Interim Low and Modified Low Fluctuating Flow Alternatives offer approaches to achieving a balance between enhancing benefits to natural resources and reducing impacts to hydropower.

Table II-7.-Summary Comparison of Alternatives and Impacts

	No Action	Maximum Powerplant Capacity	High Fluctuating Flow	Moderate Fluctuating Flow
WATER				
Streamflows (1,000 acre-feet)				
Annual streamflows				
Median annual release	8,573	8,573	8,559	8,559
Monthly streamflows (median)				
Fall (October)	568	568	568	568
Winter (January)	899	899	899	899
Spring (May)	587	587	592	592
Summer (July)	1,045	1,045	1,045	1,045
Hourly streamflows can be found in table II-2.				
SEDIMENT				
Riverbed sand (percent probability of net gain)				
After 20 years	50	49	53	61
After 50 years	41	36	45	70
Sandbars (feet)				
Active width	44 to 74	47 to 77	33 to 53	28 to 47
With habitat maintenance flows				41 to 66
Potential height	10 to 15	10 to 16	7 to 1	6 to 10
With habitat maintenance flows				9 to 14
FISH				
Aquatic food base	Limited by reliable wetted perimeter	Same as no action	Minor increase	Moderate increase
Native fish	Stable to declining	Same as no action	Same as no action	Same as no action
Non-native warmwater and coolwater fish	Stable to declining	Same as no action	Same as no action	Same as no action
Interactions between native and non-native fish	Some predation and competition by non-natives	Same as no action	Same as no action	Same as no action
Trout	Stocking-dependent	Same as no action	Same as no action	Increased growth potential, stocking-dependent

Modified Low Fluctuating Flow	Interim Low Fluctuating Flow	Existing Monthly Volume Steady Flow	Seasonally Adjusted Steady Flow	Year-Round Steady Flow
8,559	8,559	8,559	8,554	8,578
568	568	568	492	699
899	899	899	688	703
592	592	592	1,106	699
1,045	1,045	1,045	768	699
64	69	71	71	74
73	76	82	82	100
24 to 41	24 to 41	10 to 19	16 to 29	0
41 to 66			37 to 60	
6 to 9	6 to 9	3 to 5	4 to 7	0 to 1
9 to 14			8 to 13	
Potential major increase	Potential major increase	Major increase	Major increase	Major increase
Potential minor increase	Potential minor increase	Uncertain potential minor increase	Uncertain potential major increase	Uncertain potential minor increase
Potential minor increase	Potential minor increase	Potential minor increase	Potential minor increase	Potential minor increase
Potential minor increase in warm, stable microhabitats	Potential minor increase in warm, stable microhabitats	Potential minor increase in warm, stable microhabitats	Potential minor increase in warm, stable microhabitats	Potential minor increase in warm, stable microhabitats
Increased growth potential, stocking-dependent	Increased growth potential, stocking-dependent	Increased growth potential, possibly self-sustaining	Increased growth potential, possibly self-sustaining	Increased growth potential, possibly self-sustaining

Table II-7.–Summary Comparison of Alternatives and Impacts–Continued

	No Action	Maximum Powerplant Capacity	High Fluctuating Flow	Moderate Fluctuating Flow
VEGETATION				
Woody plants (area)				
New high water zone	No net change	0 to 9% reduction	15 to 35% increase	23 to 40% increase
With habitat maintenance flows				0 to 12% increase
Species composition	Tamarisk and others dominate	Tamarisk and others dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate
Emergent marsh plants				
New high water zone				
Aggregate area of wet marsh plants	No net change	Same as no action	Same as or less than no action	Same as or less than no action
WILDLIFE AND HABITAT				
Riparian habitat	*See vegetation.*			
Wintering waterfowl (aquatic food base)	Stable	Same as no action	Same as no action	Potential increase
ENDANGERED AND OTHER SPECIAL STATUS SPECIES				
Humpback chub	Stable to declining	Same as no action	Same as no action	Same as no action
Razorback sucker	Stable to declining	Same as no action	Same as no action	Same as no action
Flannelmouth sucker	Stable to declining	Same as no action	Same as no action	Same as no action
Bald eagle	Stable	Same as no action	Same as no action	Potential increase
Peregrine falcon	No effect	No effect	No effect	No effect
Kanab ambersnail	No effect	Some incidental take	Some incidental take	Some incidental take
Southwestern willow flycatcher	Undetermined increase	Same as no action	Same as no action	Same as no action

Modified Low Fluctuating Flow	Interim Low Fluctuating Flow	Existing Monthly Volume Steady Flow	Seasonally Adjusted Steady Flow	Year-Round Steady Flow
30 to 47% increase	30 to 47% increase	45 to 65% increase	38 to 58% increase	63 to 94% increase
0 to 12% increase			0 to 12% increase	
Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate
Same as or less than no action	Same as or less than no action	Less than no action	Less than no action	Less than no action
Potential increase	Potential increase	Potential increase	Potential increase	Potential increase
Potential minor increase	Potential minor increase	Uncertain potential minor increase	Uncertain potential major increase	Uncertain potential minor increase
Potential minor increase	Potential minor increase	Uncertain potential minor increase	Uncertain potential minor increase	Uncertain potential minor increase
Potential minor increase	Potential minor increase	Uncertain potential minor increase	Uncertain potential major increase	Uncertain potential minor increase
Potential increase	Potential increase	Potential increase	Potential increase	Potential increase
No effect	No effect	No effect	No effect	No effect
Some incidental take	Some incidental take	Some incidental take	Some incidental take	Some incidental take
Same as no action	Same as no action	Same as no action	Same as no action	Same as no action

Table II-7.-Summary Comparison of Alternatives and Impacts-Continued

	No Action	Maximum Powerplant Capacity	High Fluctuating Flow	Moderate Fluctuating Flow
CULTURAL RESOURCES				
Archeological sites (Number affected)	Major (336)	Major (336)	Potential to become major (263)	Moderate (Less than 157)
Traditional cultural properties	Major	Same as no action	Potential to become major	Moderate
Traditional cultural resources	Major	Same as no action	Same as no action	Increased protection
AIR QUALITY				
Regional air quality				
Total emissions (thousand tons)				
Sulfur dioxide	1,960	Same as no action	Slight reduction	Slight reduction
Nitrogen oxides	1,954			
RECREATION				
Fishing				
Angler safety	Potential danger	Same as no action	Same as no action	Moderate improvement
Day rafting				
Navigation past 3-Mile Bar	Difficult at low flows	Same as no action	Negligible improvement	Major improvement
White-water boating				
Safety	High risk at very high and very low flows	Same as no action	Negligible improvement	Minor improvement
Camping beaches (average area at normal peak stage)	Less than 7,720 square feet	Same as no action	Same as no action	Minor increase
Wilderness values	Influenced by range of daily fluctuations	Same as no action	Minor increase	Moderate increase
Economic benefits				
Change in equivalent annual net benefits (1991 nominal $ million)	0	0	0	+0.4
Present value (1991 $ million)	0	0	0	+4.6

Modified Low Fluctuating Flow	Interim Low Fluctuating Flow	Existing Monthly Volume Steady Flow	Seasonally Adjusted Steady Flow	Year-Round Steady Flow
Moderate (Less than 157)	Moderate (Less than 157)	Moderate (Less than 157)	Moderate (Less than 157)	Moderate (Less than 157)
Moderate	Moderate	Moderate	Moderate	Moderate
Increased protection	Increased protection	Increased protection	Increased protection	Increased protection
Slight reduction	Slight reduction	Slight reduction	Slight reduction	Slight reduction
Moderate improvement	Moderate improvement	Major improvement	Major improvement	Major improvement
Major improvement	Major improvement	Major improvement	Major improvement	Major improvement
Minor improvement	Minor improvement	Moderate improvement	Potential to become major improvement	Major improvement
Minor increase	Minor increase	Major increase	Potential to become major increase	Major increase
Moderate to potential to become major increase	Moderate to potential to become major increase	Major increase	Major increase	Major increase
+3.7	+3.9	+3.9	+4.8	+2.9
+43.3	+45.6	+45.6	+55.0	+23.5

Table II-7.–Summary Comparison of Alternatives and Impacts–Continued

	No Action	Maximum Powerplant Capacity	High Fluctuating Flow	Moderate Fluctuating Flow
POWER				
Annual economic cost				
1991 nominal $ million				
Hydrology	0	-1.5	2.1	54.0
Contract rate of delivery	0	0	2.5	36.7
Present value (1991 $ million)				
Hydrology	0	-17.3	24.3	624.5
Contract rate of delivery	0	0	28.9	424.5
Wholesale rate (1991 mills/kWh)	18.78	18.78	19.38 (+3.2%)	22.82 (+21.5%)
Retail rate (1991 mills/kWh)				
70% of end users	No change	No change	No change to slight decrease	No change to slight decrease
23% of end users	No change	No change	Slight decrease to moderate increase	Slight decrease to moderate increase
7% end users (weighted mean)	64.	64.1	64.6 (+0.8%)	69.7 (+8.8%)
NON-USE VALUE	*No data.*			

Modified Low Fluctuating Flow	Interim Low Fluctuating Flow	Existing Monthly Volume Steady Flow	Seasonally Adjusted Steady Flow	Year-Round Steady Flow
15.1 44.2	36.3 35.6	65.9 68.7	88.3 123.5	69.7 85.7
174.6 511.2	418.7 411.7	761.4 794.6	1,021.2 1,428.4	805.0 991.2
23.16 (+23.3%)	23.18 (+23.4%)	25.22 (+34.3%)	28.20 (+50.2%)	26.78 (+42.6%)
No change to slight decrease	No change to slight decrease	No change to slight decrease	No change to slight decrease	No change to slight decrease
Slight decrease to moderage increase	Slight decrease to moderage increase	Slight decrease to moderate increase	Slight decrease to moderate increase	Slight decrease to moderate increase
70.5 (+10.0%)	70.2 (+9.6%)	72.9 (+13.8%)	75.8 (+18.4%)	74.5 (+16.3%)