3.6 RIVERFLOW ISSUES

3.6.1 INTRODUCTION

This section considers the potential effects of interim surplus criteria on three types of releases from Glen Canyon Dam and Hoover Dam. The Glen Canyon Dam releases analyzed are those needed for restoration of beaches and habitat along the Colorado River between the Glen Canyon Dam and Lake Mead, and for a yet to be defined program of low steady summer flows to be provided for the study and recovery of endangered Colorado River fish, in years when releases from the dam are near the minimum. The Hoover Dam releases analyzed are the frequency of flood releases from the dam and the effect of flood flows along the river downstream of Hoover Dam.

3.6.2 BEACH/HABITAT-BUILDING FLOWS

The construction and operation of Glen Canyon Dam has caused two major changes related to sediment resources downstream in Glen Canyon and Grand Canyon. The first is reduced sediment supply. Because the dam traps virtually all of the incoming sediment from the Upper Basin in Lake Powell, the Colorado River is now released from the dam as clear water. The second major change is the reduction in the high water zone from the level of pre-dam annual floods to the level of powerplant releases. Thus, the height of annual sediment deposition and erosion has been reduced.

During the investigations leading to the preparation of the *Operation of Glen Canyon Dam Final EIS* (Reclamation, 1995b), the relationships between releases from the dam and downstream sedimentation processes were brought sharply into focus, and flow patterns designed to conserve sediment for building beaches and habitat (i.e., beach/habitat-building flow, or BHBF releases) were identified. The BHBF releases are scheduled high releases of short duration that exceed the hydraulic capacity of the powerplant. Such releases were presented as a commitment in the ROD (Reclamation, 1996e) for the *Operation of the Glen Canyon Dam FEIS*, at a then-assumed frequency of one in five years.

In addition to the BHBF releases described above that exceed the hydraulic capacity of the Glen Canyon Powerplant, the *Operation of Glen Canyon Dam FEIS* identified the need for Beach/Habitat Maintenance Flow releases which do <u>not</u> exceed the hydraulic capacity of the powerplant. These flows were designed to prevent backwater habitat from filling with sediment and to reduce vegetation on camping beaches in years between BHBFs. BHBF releases and Beach/Habitat Maintenance Flows serve as a tool for maintaining a mass balance of sediment in Glen Canyon and Grand Canyon.

3.6.2.1 METHODOLOGY

The frequencies at which BHBF releases from Glen Canyon Dam would occur under baseline conditions and under operation of the interim surplus criteria alternatives were estimated through the use of modeling as described in Section 3.3.

The model was configured to simulate BHBF releases by incorporating the BHBF triggering criteria (contained in Section 3.6.2.2) into the Glen Canyon Dam operating rules. The model was also configured to make no more than one BHBF release in any given year.

3.6.2.2 AFFECTED ENVIRONMENT

Sediment along the Colorado River below Glen Canyon Dam is an important and dynamic resource which affects fish and wildlife habitat along the river, creates camping beaches for recreation, and serves to protect cultural resources. Except for remnants of high river terraces deposited prior to the closure of Glen Canyon Dam, the now limited sediment supply that exists along the river channel is affected by dam operations.

Since construction of Glen Canyon Dam, the measured suspended sediment load (sand, silt, and clay) at Phantom Ranch (in the Grand Canyon) averages 11 million tons per year. Most of this load comes from the Paria River and the Little Colorado River. Flash floods from other side canyons also contribute to the sediment supply (Reclamation, 1995b). The suspended sediment load is sporadic in occurrence, depending on Glen Canyon Dam releases and tributary inputs.

Beneficial sediment mobilization and deposition below Glen Canyon Dam depends on the interaction of two occurrences for full effectiveness: the addition of sediment to the river corridor and BHBF releases. The higher energy of BHBF releases mobilizes suspended and riverbed-stored sand and deposits it as beaches in beach and shoreline areas. Once a BHBF release has been made, additional sediment supply from tributary inflows is needed before subsequent BHBF releases are fully effective in promoting further beach and sandbar deposition along the river.

Subsequent to the ROD cited above, the representatives of the AMP further refined specific criteria under which BHBFs would be made. The criteria provide that under the following two triggering conditions, BHBF releases may be made from Glen Canyon Dam:

1. If the January forecast for the January-July unregulated spring runoff into Lake Powell exceeds 13 maf (about 140 percent of normal) when January 1 content is greater than 21.5 maf; or
2. Any time a Lake Powell inflow forecast would require a monthly powerplant release greater than 1.5 maf.

Research concerning the relationships among dam operations, downstream sediment inflow, river channel and sandbar characteristics, and particle-size distribution along the river is ongoing.

3.6.2.3 ENVIRONMENTAL CONSEQUENCES

The effects of the interim surplus criteria alternatives on BHBF releases from Glen Canyon Dam were analyzed in terms of the yearly frequency at which BHBF releases could be made. Specifically, the frequency was indicated by the occurrence of one or both of the triggering criteria cited above, during a calendar year. The following discussion presents probability of occurrence under baseline conditions, and then compares the probability of BHBF releases under each interim surplus criteria alternative with the baseline conditions.

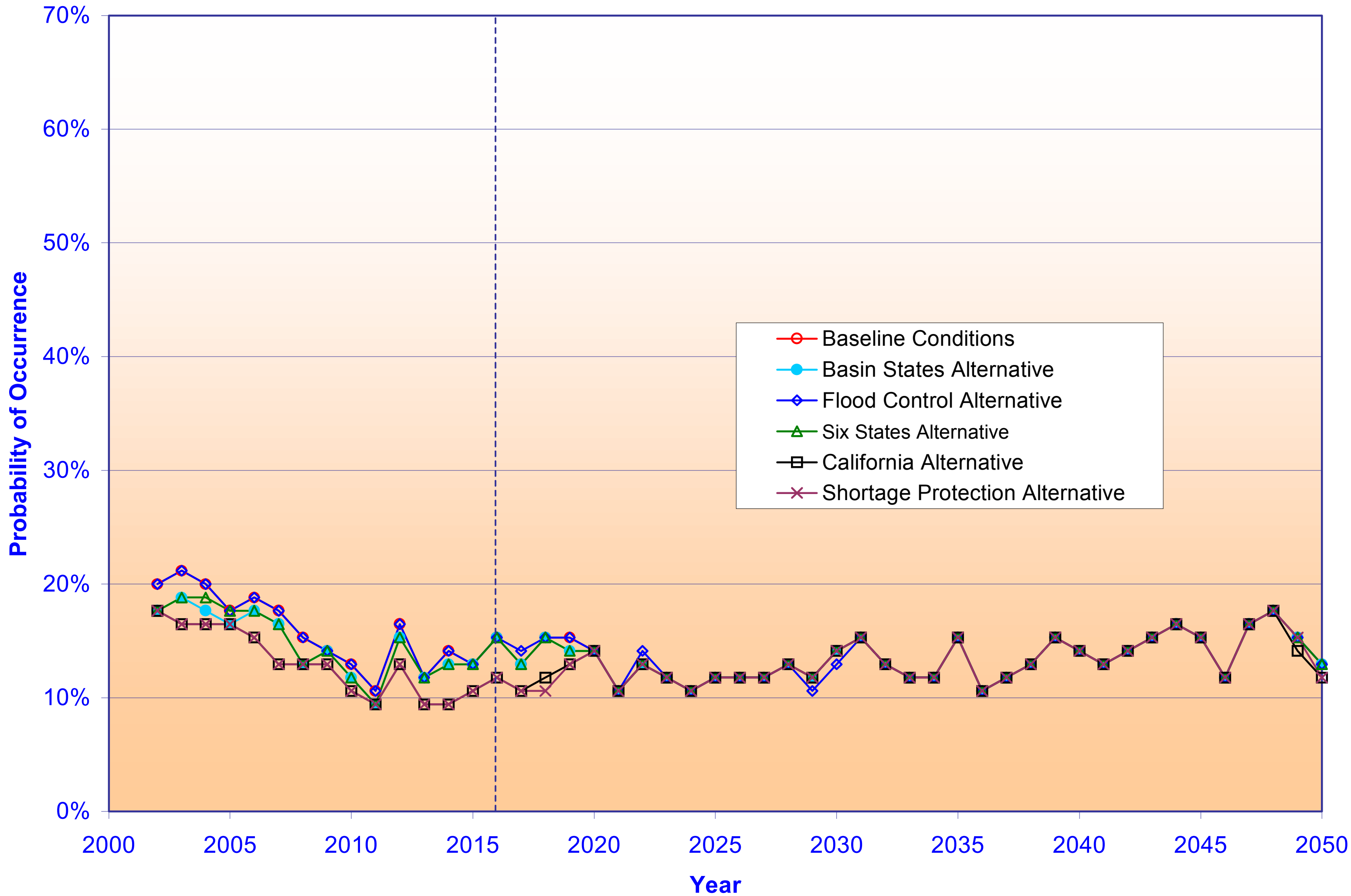
Figure 3.6-1 shows the probabilities that BHBF releases could be made under baseline conditions and the action alternatives. The plots show that the probabilities will decrease over the first decade to an irregular range of approximately 10 to 15 percent or lower, which is maintained until a slight rising trend appears in the last 15 years of the period of analysis. The trends result from the interaction of various factors, including projected increases in depletions by the Upper Division states and the requirements for equalization of storage in Lakes Powell and Mead. The operational parameter most directly comparable to the plotted relationships is the future median water level of Lake Powell. As can be seen on Figure 3.3-6, the median level of the reservoir is projected to recover somewhat in the last 15 years of the period of analysis. This correlates to the slight rise in BHBF release probabilities in the final 15 years.

Table 3.6-1 summarizes the BHBF release probabilities during the interim period and the subsequent period to 2050, based on the data plotted in Figure 3.6-1. The table reflects the higher average probability during the interim period than during the succeeding period ending in 2050.

Table 3.6-1
Probabilities of BHBF Releases from Glen Canyon Dam

Period	Percent of Time That Conditions Needed for BHBF Releases Would Occur at Lake Powell					
	Baseline Condition	Basin States Alternative	Flood Control Alternative	Six States Alternative	California Alternative	Shortage Protection Alternative
Through 2016	15.9%	14.8%	15.9%	14.9%	13.0%	13.0%
2017-2050	13.5%	13.4%	13.5%	13.4%	13.2%	13.2%

Figure 3.6-1
Lake Powell Releases
Probability of Occurrence of BHBF Flows



3.6.2.3.1 Baseline Conditions

During the interim period, the average probability under baseline conditions that BHBF releases could be made in a given year is approximately 15.9 percent, which is equivalent to about one year in six. During the subsequent period ending in 2050, the average probability is approximately 13.5 percent, which is equivalent to about one year in seven. The reduction in probability after 2015 under baseline conditions results from the fact that with time, the Lake Powell water level will probably decline because of increased Upper Basin depletions, as illustrated in Section 3.3. This water level decline would gradually reduce the probability that the BHBF triggering criteria would occur.

3.6.2.3.2 Basin States Alternative

During the interim period, the average probability under the Basin States Alternative that BHBF releases could be made in any single year is approximately 14.8 percent, which equates to approximately one year in seven. During the subsequent period ending in 2050, the average probability is approximately 13.4 percent, which is equivalent to about one year in seven.

3.6.2.3.3 Flood Control Alternative

During the interim period, the average probability under the Flood Control Alternative that BHBF releases could be made in any single year is approximately 15.9 percent, which equates to approximately one year in six. During the subsequent period ending in 2050, the average probability is approximately 13.5 percent, which is equivalent to about one year in seven.

3.6.2.3.4 Six States Alternative

During the interim period, the average probability under the Six States Alternative that BHBF releases could be made in any single year is approximately 14.9 percent, which equates to approximately one year in seven. During the subsequent period ending in 2050, the average probability is approximately 13.4 percent, which is equivalent to about one year in seven.

3.6.2.3.5 California Alternative

During the interim period, the average probability under the California Alternative that BHBF releases could be made in any single year is approximately 13.0 percent, which equates to approximately one year in eight. During the subsequent period ending in 2050, the average probability is approximately 13.2 percent, which is equivalent to about one year in eight.

3.6.2.3.6 Shortage Protection Alternative

During the interim period, the average probability under the Shortage Protection Alternative that BHBF releases could be made in any single year is approximately 13.0 percent, which equates to approximately one year in eight. During the subsequent period ending in 2050, the average probability is approximately 13.2 percent, which is equivalent to about one year in eight.

3.6.3 LOW STEADY SUMMER FLOW

3.6.3.1 AFFECTED ENVIRONMENT

During preparation of the *Operation of Glen Canyon Dam FEIS*, it was hypothesized that steady flows with a seasonal pattern may have a beneficial effect on the potential recovery of special status fish species down stream of Glen Canyon Dam. Accordingly, development of an experimental water release strategy was recommended by the Service to achieve steady flows when compatible with water supply conditions and the requirements of other resources. The strategy included developing and verifying a yet to be defined program of experimental flows which would include providing high steady flows in the spring and low steady flows in summer and fall during water years when a volume of approximately 8.23 maf is released from Glen Canyon Dam. This strategy, commonly referred to as the low steady summer flow program, was contained in the *Final Biological Opinion on the Operation of Glen Canyon Dam* (Service, December 1994c), and recognized in the ROD for the *Operation of Glen Canyon Dam FEIS* (USDI, 1996).

3.6.3.2 ENVIRONMENTAL CONSEQUENCES

The ability to test the low steady summer flow release strategy at Glen Canyon Dam according to the ROD could be affected by the implementation of interim surplus criteria. This matter was investigated by analyzing the model releases from Glen Canyon Dam to determine the probabilities at which minimum releases of 8.23 maf per water year would occur.

Figure 3.6-2 shows the annual probabilities of minimum releases from Glen Canyon Dam during the period of analysis. Note that the first year plotted is 2003, since 2003 would be the first complete water year (October 1, 2002 through September 30, 2003) during the interim period. The plots show that the probabilities increase through 2023, from approximately 20 to 25 percent to approximately 60 percent, which is maintained until another increase to 67 percent occurs during the last 15 years of the analysis. The trends result from the interaction of various factors that affect annual releases from Glen Canyon Dam, including projected increases in depletions by the Upper Division states and the requirements for equalization of storage in Lakes Powell and Mead.

Figure 3.6-2
Lake Powell Releases
Probability of Approximately 8.23 maf Annual Release

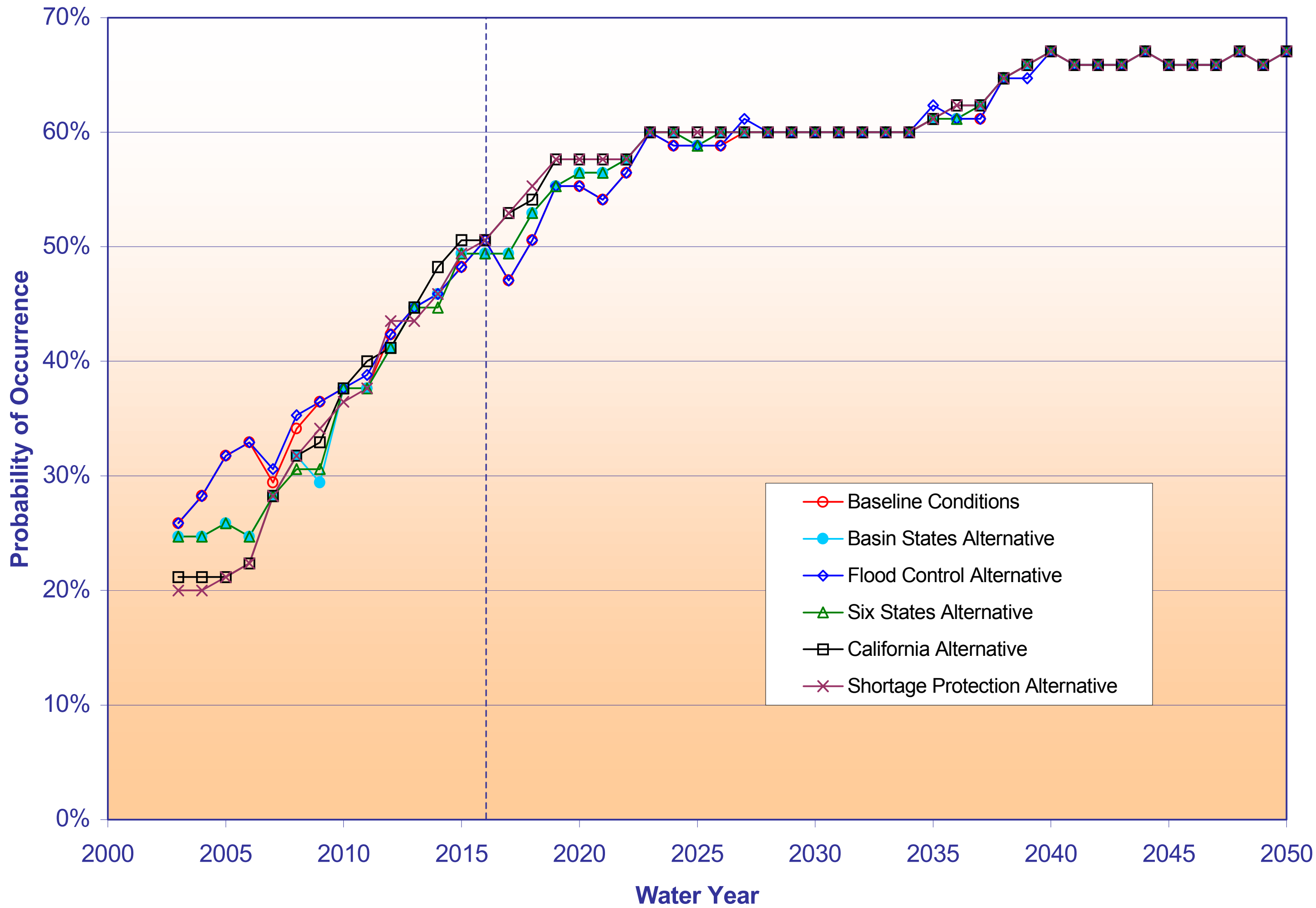


Table 3.6-2 summarizes the probabilities that minimum releases would occur during the interim period and the subsequent period to 2050, based on data plotted in Figure 3.6-2. Probabilities are summarized by water year because releases from Glen Canyon Dam are accounted for by water year under provisions of the LROC. The results indicate that under baseline conditions, the probability of 8.23 maf annual releases from the dam is approximately 38.2 percent during the interim period and 61.6 percent during the subsequent period ending in 2050. The probabilities under all alternatives are similar to those under baseline conditions after 2006. Under the Flood Control Alternative, the probability is approximately the same as for baseline conditions, as shown on Table 3.6-2. The probabilities under the remaining four interim surplus criteria alternatives during the interim period are one to two percent less than under baseline conditions. During the subsequent period through 2050, the probabilities resulting from the remaining four surplus criteria would be one to two percent higher than under baseline conditions.

Table 3.6-2
Probability of Minimum Glen Canyon Dam Releases
(Annual Releases of 8.23 maf)

Period (Water Years)	Baseline Condition	Basin States Alternative	Flood Control Alternative	Six States Alternative	California Alternative	Shortage Protection Alternative
Through 2016	38.2%	36.3%	38.4%	36.2%	35.8%	36.3%
2017-2050	61.6%	61.9%	61.6%	61.9%	62.2%	62.1%

Note: The "water year" on which this accounting is based extends from October 1 to September 30.

3.6.4 FLOODING DOWNSTREAM OF HOOVER DAM

Under the BCPA, flood control was specified as the project purpose having first priority for the operation of Hoover Dam. Subsequently, Section 7 of the Flood Control Act of 1944 established that the Secretary of War (now the Corps) will prescribe regulations for flood control for projects authorized, wholly or in part, for such purposes.

The Los Angeles District of the Corps published the current flood control regulations in the *Water Control Manual for Flood Control, Hoover Dam and Lake Mead Colorado River, Nevada and Arizona* (Water Control Manual) dated December 1982. The Field Working Agreement between Corps and Reclamation for the flood control operation of Hoover Dam and Lake Mead, as prescribed by the Water Control Manual, was signed on February 8, 1984. The flood control plan is the result of a coordinated effort between the Corps and Reclamation; however, the Corps is responsible for providing the flood control regulations and has authority for final approval. The Secretary is responsible for operating Hoover Dam in accordance with these regulations. Any deviation from the flood control operating instructions must be authorized by the Corps.

This analysis addresses the flooding that occurs along the Colorado River below Hoover Dam. The evaluation focuses on the change in the probability that various "threshold" flows would be released from Hoover, Davis and Parker Dams. A threshold flow rate is one at which flood damages have been found to begin to occur along the river. The analysis is not limited to dam releases made expressly in connection with flood control operation, but also includes releases made for water supply and power generation purposes. For example, power generation requirements can cause releases from Hoover Dam to exceed 19,000 cfs, with such releases being regulated in Lake Mohave downstream. In addition, the analysis presents data on land use and anticipated flood damages that were developed by the Los Angeles District Corps of Engineers in the *Review of Flood Control Regulations, Colorado River Basin, Hoover Dam, July 1982* (Corps, 1982).

3.6.4.1 AFFECTED ENVIRONMENT

Historical flows downstream of Hoover Dam have caused flood damages at various points along the lower Colorado River. A key threshold level was established as a result of flooding that occurred in 1983 when uncontrolled releases occurred over the Hoover Dam spillways. The high Colorado River flows caused damages primarily to encroachments in the Colorado River floodplain. In addition, several lower thresholds that are significant along various reaches are evaluated in the following subsections.

The Colorado River Floodway Protection Act (Floodway Act) originated from Congressional hearings held in 1983 following the flood. The Floodway Act called for the establishment of a federally declared floodway from Davis Dam to the SIB. The floodway is to accommodate either a 1-in-100 year river flow consisting of controlled releases and tributary inflow, or a flow of 40,000 cfs, whichever is greater. As discussed in Section 3.3.1, certain flood release rates from Hoover Dam are required depending on flood flow into Lake Mead and the amount of available storage space.

Estimates of development in the flood plains below Hoover Dam were last made by the Corps based on 1979 data (Corps, 1982). These data are presented in Table 3.6-3.

3.6.4.1.1 Hoover Dam to Davis Dam

Critical flood flows for the reach between Hoover Dam and Davis Dam are 19,000 cfs, 28,000 cfs, 35,000 cfs, 43,000 cfs, and 73,000 cfs.

3.6.4.1.2 Davis Dam to Parker Dam

The river is within levees for most of the reach from Davis Dam to Parker Dam. Historical flood flows have caused damage to some of the bank protection. Minor damage begins to occur at flows of 26,000 cfs.

Table 3.6-3
Development in Flood Plains Between Hoover Dam and SIB, 1979 Data[1]

	(Number of structures unless otherwise noted)					
Flood Flow (cfs)	Mobile Homes	Residential	Commercial/ Industrial	Public/ Semipublic	Agriculture (acres)	Recreation Facilities [5]
100,000	1,609	1,457	74	70	55,089	278
71,000 [2]	758	786	54	66	15,861	277
48,000[3]	164	198	13	10	2,671	277
38,000[4]	101	138	4	6	176	232
28,000	17	44	1	0	90	201

[1] Corps of Engineers, Colorado River Basin Hoover Dam, Review of Flood Control Regulations. Final Report, July 1982. Table C-1.
[2] 78,000 cfs at Needles.
[3] 50,000 cfs at Needles.
[4] 40,000 cfs at Needles.
[5] Recreation facilities are primarily boat docks that would sustain significant damage with high flows.

3.6.4.1.3 Hoover Dam to Davis Dam

Critical flood flows for the reach between Hoover Dam and Davis Dam are 19,000 cfs, 28,000 cfs, 35,000 cfs, 43,000 cfs, and 73,000 cfs.

3.6.4.1.4 Davis Dam to Parker Dam

The river is within levees for most of the reach from Davis Dam to Parker Dam. Historical flood flows have caused damage to some of the bank protection. Minor damage begins to occur at flows of 26,000 cfs.

3.6.4.1.5 Parker Dam to Laguna Dam

Below Parker Dam, significant damage to permanent homes has occurred during releases within the flood operation criteria. This area has been further developed since the flood operations in 1983. Minor damage begins at 19,000 cfs along the Parker Strip (the reach of river between Parker Dam and the town of Parker, Arizona). Backwater regions, which function as wildlife refuges and recreational areas, accumulated sediment, and in some cases, became isolated from the Colorado River. Historical flood flows have also resulted in damage to infrastructure of government agencies.

3.6.4.1.6 Laguna Dam to SIB

Below Laguna Dam, the banks of the Colorado River are not protected. Historical flood flows have resulted in significant damage to the banks. Associated increases of groundwater level in the Yuma area have also resulted in some lands becoming water logged and caused drains to cease functioning. During the scoping process for this

DEIS, a letter from the Yuma County Water Users' Association states that "[o]ur landowners are harmed by such releases, particularly should the flood control releases be required to go beyond the 19,000 cubic feet per second Hoover release level" (Pope, 1999). The letter indicates that a flood control release of 28,000 cfs or greater could result in upwards of $200 million in damages to the Yuma area. Other injured parties could include the City of Yuma, the County of Yuma, Cocopah Indian Tribe, the Gila Valley, Bard Irrigation District, and the Quechan Indian Tribe.

Additional flows of concern include:

- Laguna Dam south to Pilot Knob: 9,000 cfs is the threshold value. Flows of 10,000 cfs to 11,000 cfs impact leach fields of trailer parks located within levees.

- Pilot Knob to SIB: 15,000 cfs is a threshold value. Above that level, high groundwater, localized crop damage and damage to the United States Bypass Drain occur.

3.6.4.2 ENVIRONMENTAL CONSEQUENCES

The effects of the interim surplus criteria on flood flows were analyzed by determining the probabilities that releases from Davis and Parker Dams would reach or exceed certain flow rates that have been found to be thresholds for damages. In addition, the analysis addressed the probabilities that releases of various magnitudes would be made from Hoover Dam corresponding to the required flood control releases discussed in Section 3.3.1.2, Operation of Hoover Dam. The release probabilities were determined from results of river system modeling described in Section 3.3. The results of the analysis are shown in Table 3.6-4.

The results portrayed on Table 3.6.3 show that except for the Flood Control Alternative, the action alternatives would reduce the probability of flows at or above the damage thresholds.

The Corps estimated the likely damage to development based on the 1979 land use data (Corps, 1982). These data are presented in Table 3.6-5.

The data on direct, physical damages presented in Table 3.6-5 are based on simultaneous flooding along all reaches of the river from Hoover Dam to the SIB. The data show that damages increase much more rapidly than the size of the flow. For example, a 48,000-cfs flow has 15 times the impact of a 22,000-cfs flow, while the flow increases by only 2.2 times. A 48,000 cfs flow has a less than one-in-500 probability of occurring in any one year, while a 22,000 cfs flow has a greater than one-in-20 probability of occurring in any one year under all alternatives.

Table 3.6-4
Discharge Probabilities from Hoover, Davis and Parker Dams

Release Point	Discharge (cfs)[1]	Percent of Years With Flows Greater Than or Equal to Discharge					
		Baseline Conditions	Basin States Alternative	Flood Control Alternative	California Alternative	Six States Alternative	Shortage Protection Alternative
Years 2002 to 2016							
Hoover Dam	19,000	20.8	18.8	21.2	16.3	18.6	16.9
Hoover Dam	28,000	7.5	7.2	7.7	5.5	7.1	5.8
Hoover Dam	35,000	2.1	2.0	2.1	1.6	2.0	1.7
Hoover Dam	40,000	0.2	0.2	0.2	0.2	0.2	0.2
Hoover Dam	73,000	0.0	0.0	0.0	0.0	0.0	0.0
Davis Dam	26,000	8.6	8.1	9.1	7.0	8.0	7.1
Parker Dam	19,500	10.4	9.4	11.3	7.8	9.3	8.0
Years 2017 to 2050							
Hoover Dam	19,000	14.6	14.1	14.9	13.9	14.1	13.8
Hoover Dam	28,000	4.0	3.8	4.2	3.7	3.8	3.6
Hoover Dam	35,000	0.9	1.7	0.9	0.8	0.9	0.8
Hoover Dam	40,000	0.2	0.1	0.2	0.1	0.2	0.1
Hoover Dam	73,000	0.0	0.0	0.0	0.0	0.0	0.0
Davis Dam	26,000	4.8	4.6	5.0	4.4	4.6	4.5
Parker Dam	19,500	5.9	5.7	6.1	5.6	5.7	5.6

[1] Average monthly discharge

Table 3.6-5
Estimated Flood Damages Between Hoover Dam and the SIB
(1979 level of development and 2000 price level[1])

Flood Flow (cfs)	Flood Damages
100,000	$201,000,000
71,000 [2]	$ 55,700,000
48,000[3]	$ 9,210,000
38,000[4]	$ 1,550,000
22,000	$ 610,000

[1] Corps of Engineers, Colorado River Basin Hoover Dam, Review of Flood Control Regulations. Final Report, July 1982. Table C-5. Adjusted from June 1978 to March 2000 price level by Consumer Price Index-all Urban Consumers. (June 1978 is 65.2, March 2000 is 167.8, Adjustment factor: 2.57.)
[2] 78,000 cfs at Needles
[3] 50,000 cfs at Needles
[4] 40,000 cfs at Needles