Report of the Spike Flow Subgroup
Glen Canyon Dam Technical Work Group
October 27, 1997

Introduction

A provision for a Beach/Habitat Building Flow (BHBF) was included in the preferred alternative of the Glen Canyon Dam Final EIS. As discussed in the GCDEIS on page 40, the BHBF would involve releases in excess of powerplant capacity and would be considered in low reservoir storage years to rejuvenate beaches and backwater areas. However, in the Record of Decision on the EIS, the Secretary of the Interior determined that the objectives of the BHBF were to be accomplished in high reservoir storage years using releases in excess of powerplant capacity required for dam safety purposes.

Whereas the ROD established the framework for implementing BHBF's, it left unresolved the technical criteria for determining whether sufficient risk of releases above powerplant capacity existed to schedule a BHBF. It did not specify what risk of a spring spill needed to exist in order to implement a BHBF in the March/April timeframe currently favored by river resource managers.

The purpose of this subgroup exercise is to evaluate alternative spill avoidance operations and risk thresholds and recommend specific criteria for determining when a BHBF can be prescribed as a part of spill avoidance operations. In this report we describe (1) the evolution of thinking regarding the role of spills in downstream resource management, (2) historic characteristics of powerplant bypasses, (3) how spill risks from Glen Canyon Dam are modeled, (4) alternative BHBF decision criteria, (5) a recommendation for BHBF "triggering" criteria, and (6) a recommendation for additional studies.

In the following report several terms are used to describe powerplant bypasses from Glen Canyon Dam. Unavoidable bypasses are described as "spills" or "flood flows" and usually occur in the May through July time period as the reservoir storage nears the full level. Intentional bypasses in anticipation of a high risk of unavoidable bypasses have been described in the past as a "spike flow" but are herein labeled as a BHBF. A test of such a BHBF was conducted in March/April 1996.

Following page 9 of this report are the two graphs and the table referred to in the text. An appendix containing the three sets of computer runs described in the alternative BHBF decision criteria section follows these graphs and table.

Background - Evolution of Spill Expectations

GCES conclusions

The majority of the GCES Phase 1 research work took place in the mid-1980's, when the releases from Glen Canyon Dam were at an all time high since the construction of the dam. Flows were generally high and constant, providing almost no opportunity for the researchers to observe the impacts of fluctuating flows. The flood flows were so different than historic releases and caused such large effects downstream that they had a great influence on GCES recommendations.

On page 83 of the final GCES Phase 1 report, the first and foremost conclusion was that "Adverse downstream consequences are caused primarily by sustained flood releases significantly greater than powerplant capacity and by fluctuating releases", noting the erosive effect of floods on sand deposits and vegetation. Generally, these conclusions suggested the elimination or reduction of flood flows. Significant effort was taken to understand the operational causes of spills, and in 1987 modifications to monthly release patterns were made by Reclamation to reduce the frequency of spills from about 1 year in 4 to about 1 year in 20. Due to the limited number of years of actual dam operation and forecasts, there was uncertainty associated with these estimates, but a reduction in this frequency was certainly desired by the researchers involved in GCES.

Despite the enormous beaches created particularly by the 1983 spill event, the general thinking at that time was that there was a very limited supply of sediment below Glen Canyon Dam and that spills destructively moved much of this sediment out of the Grand Canyon.

1992 Grand Canyon Protection Act

In the committee report accompanying this legislation, the Congress continued this thinking of adverse impacts by stating that "Flood releases from the dam erode beaches used by recreational rafters and campers. The river's now reduced sediment loads are inadequate to replenish beaches, even if flood releases occur once every twenty years. Flood releases destroy riparian vegetation and birds." The Act did not specify remedial measures, but seemed to imply that even the aggressive spill avoidance strategy that had been implemented to reduce spill frequency might be insufficient.

GCDEIS Transition Work Group and Sediment Balance

After the passage of the GCPA, the thinking of some sediment experts began to change, primarily as the result of the hypothesis that the sediment rating curves below the dam were not static with time. Additional thought was also being given to the location of stored sediment in the canyon and the mechanisms for moving sediment from the channel bottom to eddy areas. Significant modeling by the sediment researchers changed to a great degree the way in which transport mechanisms were viewed. The long term balance of sediment in the Grand Canyon continued to be an important issue in these discussions.

Some discussion also considered the concept that flood flows counteracted the possible adverse impacts that fluctuations had on beach erosion, thus rebuilding the deposits that would eventually slough back into the eddies, regardless of the nature of the powerplant operations. Some suggested that more frequent floods could allow higher levels of fluctuations.

Interpretation of Statute, the 1996 AOP Agreement, the GCDEIS ROD, and Risk

With this evolving positive view towards spills, a desire for a test of the GCDEIS Beach Habitat Building Flow was expressed by the Transition Work Group beginning in 1994. This request for a purposeful powerplant bypass was strongly opposed by the Basin States, claiming a violation of the 1968 Colorado River Basin Project Act provision of avoiding anticipated spills, interpreted as powerplant bypasses. This opposition created an impasse that blocked such a test.

Additional discussions between members of the Transition Work Group and the Basin States resulted in a proposal for a modification of the GCDEIS preferred alternative, that of moving Beach Habitat Building Flows (BHBF) from years of low reservoir conditions (when spills would not be required for hydrologic reasons) to years of high reservoir conditions and high inflows. Thus a BHBF would occur in years when there was an expectation of having a hydrologically induced spill. Since the researchers had targeted the March-April timeframe as the preferred time for a BHBF, the water that would have been expected to spill in June or July would be pre-released earlier in the year to accomplish the intent of the BHBF. Some researchers had concerns about the magnitude of releases in temporally adjacent months of the BHBF, citing the potential for high powerplant releases to negate the beach building gains made during the BHBF. Long term sediment balance continued to be a concern. However, the benefits of reaching a compromise solution outweighed these possible negative impacts and this agreement was institutionalized in the 1996 Annual Operating Plan for the Colorado River, signed by the Secretary of the Interior in December 1995.

The following March and April 1996, the requested test of the BHBF occurred with a release of 45,000 cfs for a period of 7 days. This flow included a powerplant bypass of about 15,000 cfs. Such a release was not required for hydrologic reasons, but was allowed by the Basin States as a one-time test as a result of the agreement contained in the 1996 AOP.

In December 1996, the GCDEIS Record of Decision was signed by the Secretary of the Interior and included this modification of the preferred alternative. The BHBF negotiations did not include an explicit discussion of the hydrologic situation that should trigger a BHBF. Some recognition was given to the concept that this risk could be something less than the 50 percent level produced by using the most probable forecast from the National Weather Service as the inflow hydrology, but those discussions were left unresolved at the time of the signing of the GCDEIS ROD. At the April 1997 BHBF symposium, the issues of BHBF frequency, high powerplant releases, and BHBF benefits were again raised. It is these issues of risk and frequency that the TWG spill subgroup now addresses.

Historic Characteristics of Powerplant Bypasses

As a result of the concern in the late-1980's over continued spills, Reclamation extensively analyzed the causes, frequency and magnitude of spills. The period of forecasts and operations from 1966 through 1989 was used to model these three characteristics. We found that several parameters of reservoir operation most significantly affect spills, in the following order of significance: the aggressiveness with which forecast changes are incorporated into monthly release schedules, the target storage levels each July 31, and the initial reservoir storage conditions each January 1. Reclamation developed a simple operation model which allowed these variables to be altered and predicted the results in terms of monthly release patterns and spills. We found that as of 1986 the long term frequency of spills using the pre-GCES operating practices was about 1 year in 4.

Moving from a frequency of 1 in 4 to 1 in 20 required changes to historic practices. The largest change was in the manner in which forecast changes altered monthly release patterns during the winter and early spring. Two of the primary reasons that the dam spilled as much as it did during the 1980's was the purposeful scheduling of (1) releases close to powerplant capacity during June and July and (2) storage near to the capacity of the reservoir at the end of July. This practice minimized the operational flexibility during the peak of the spring runoff to accommodate the forecast increases which occurred in 1983 - 1986.

By adopting a July 31 target storage buffer of about 0.5 MAF and by incorporating forecast increases as soon as possible into the current month's releases, the frequency of spills was reduced. The historic spills which occurred in 1985 and 1986 could thus be eliminated and the those of 1983 and 1984 could be reduced.

Another important factor in this analysis was the uprating of the Glen Canyon Dam generators which occurred in the mid-1980's, increasing the powerplant releases capacity to 33,200 cfs from about 27,000 cfs. This increased capacity is not fully available due to effects of reservoir head and transformer and generator operating factors. A more practicable capacity may be closer to 31,000 cfs. This additional release capability increases the ability to avoid spills, and thus reduces the frequency and magnitude of such spills.

Modeling the Risk of Spills from Glen Canyon Dam

To further understand how spills occurred, we once again used the computer model developed in 1987 that Reclamation had used in initially reducing spill frequency. We updated the storage capacity of Lake Powell and the target storage levels for January 1 and July 31 to account for the recent sediment survey, and extended the data set through 1997.

Upstream reservoirs were modeled according to recent constraints placed on them by consultations under the Endangered Species Act. This resulted in scheduled high spring flows at the Flaming Gorge, Aspinall, and Navajo Dams. Glen Canyon Dam was modeled with an initial release pattern that scheduled higher flows in January and February and lower flows in April and

May, with limited releases in June and July to preserve late-season release flexibility to accommodate forecast increases. The monthly Glen Canyon release capacity was assumed to be about 1.9 MAF. The method of scheduling winter and spring monthly releases needs to be clearly explained. In attempting to model our operation to avoid spills, several degrees of aggressiveness in scheduling these releases were analyzed. In other words, if the forecast changed as the operation progressed through the winter and spring, this analysis attempted to answer the question "How should our operation react to these forecast changes?". In the past, an aggressive reaction to forecast changes was the key technique we used to reduce spill frequency. For example, if the forecast increased by 2 MAF at the beginning of April, then releases in April would immediately be increased, perhaps to maximum capacity, in order to preserve as much flexibility for future months as practicable.

By reviewing the results of these computer runs, we then determined the frequency of unavoidable spills as well as the circumstances under which a BHBF would be scheduled, all these under a range of BHBF-triggering and "forecast-aggressiveness" assumptions.

Alternative BHBF Decision Criteria

The subgroup considered several methods that could serve as threshold triggering mechanisms for implementing BHBF's. These include (1) various levels of risk associated with forecast error curves previously discussed with the TWG, (2) monthly volumes, and (3) runoff forecast percentages. Each of these methods attempts to answer the question, "Under what conditions should a BHBF be triggered?".

As these alternatives were analyzed, an attempt was made to eliminate operational errors in reacting to runoff forecasts, errors of omission as well as commission. An omission error would be to not release a March BHBF when a spill actually would occur later in the year, accompanied by high powerplant releases. As an example, Graph 1 shows the evolving spring runoff forecast during water year 1985. The drop in the forecast on March 1 would have dissuaded the release of a BHBF, when in actuality the dam would have spilled later in the spring when the inflow was much higher than expected. A commission error is the release of a BHBF when a subsequent spill would not have actually occurred. Graph 2 shows this type of situation in water year 1972, where the runoff forecast was originally high early in the winter, but dropped dramatically in the spring as the result of dry climatic conditions.

A range of forecast risks from 2 to 50 percent were investigated. A very liberal risk level of 2 percent recognizes all actual spill years but also allows BHBF's in many years in which there was no justification for such. The years 1970 and 1971 are good examples of such and had only slightly above normal runoff with very little risk of spill. Requiring high levels of risk as a threshold more accurately handles the non-spill years, but fails to identify many of the actual spill years. Because of the complexity in evaluating spill risk using forecast error curves, it was suggested that forecasts should be evaluated from a "percent of normal" basis. The subgroup found that such an approach was actually an alternate expression for spill risk, but more straightforward and simpler to employ. Various percent of normal thresholds were evaluated, tying these values to both historic spills conditions and powerplant release capacity during the January through July period.

Monthly volumes of 1.2 and 1.5 MAF were evaluated as possible triggers for implementing a BHBF prior to the release of monthly volumes greater than these values. This approach was proposed by several members of the Transition Work Group earlier in 1997 as Reclamation was forced to release water at rates of 27,000 cfs as the result of very high runoff forecasts (greater than 150 percent of normal).

The use of the runoff forecast as a percent of normal was also investigated, recognizing that risk of spills is closely tied to high runoff volumes. A "percent of normal" forecast could be established as a trigger. Variables in this approach include the timing of such a determination and the magnitude of the forecast percentage.

Recommended Trigger Conditions for a Purposeful BHBF

The subgroup has thoroughly discussed and analyzed this issue of risk of spills. We have found that an answer to the question of a triggering risk level to be very subjective. However with some concerns as described below, we recommend the following process for determining the appropriateness of a BHBF:

1 - We conclude that the current January 1 target storage content of 21.5 MAF is appropriate, unless and until operating experience or modeling shows otherwise.

2 - We conclude that the current July 31 target storage content of 23.8 MAF (0.5 MAF storage buffer) is appropriate.

3 - We conclude that the aggressiveness of high winter releases should be moderated to some extent, by (1) seeking to maintain a more uniform level of monthly releases resulting from forecast changes, and (2) by limiting January monthly releases to 1.2 MAF unless driven to higher levels by large forecasted spring runoff that would require higher releases to safely pass the spring runoff, discussed in item number 4 below.

This conclusion recognizes that high powerplant releases have significant effects on downstream resources, not limited to just sediment transport. Attempting to limit the January release volume to 1.2 MAF reduces the likelihood that high winter releases in excess of 25,000 cfs would occur without being preceded by a BHBF and moves the timing of the BHBF determination closer to the March/April target time frame.

4 - We recommend that a BHBF in excess of powerplant capacity could be released upon meeting the following conditions, subject to the environmental appropriateness of such a flow:

a - When the January or February forecast for the January - July spring runoff exceeds 13 MAF (about 140 percent of normal) and would likely precipitate extremely large monthly powerplant releases throughout the runoff period. a BHBF would be triggered to cause a "pre-emptive strike". Such an early BHBF would mitigate against the impacts of pending extremely high powerplant releases or actual spills which could occur later in the runoff period. Such a BHBF would not materially reduce the risk of future spills since the volumes of BHBF's are relatively small, but would accomplish the goal of moving sediment from the main channel to the side channels and eddies. Subsequent high powerplant releases to control the spring runoff then would have a less detrimental effect on sediment resources. These BHBF's would occur very early in the runoff forecast (mid-January through March).

The value of 140 percent was chosen as the threshold value in an attempt to balance the number of false alarms (BHBF's that after-the-fact were not actually required) with the number of missed spills (actual spring spills that were unforeseen earlier in the runoff season). This percentage value of 140 percent is near the level of the January forecast during 1986, an historic spill year.

b - anytime an increasing forecast would require a powerplant monthly release greater than 1.5 MAF or use of the 0.5 MAF storage buffer, a BHBF could be released prior to increasing the releases above 25,000 cfs. Such conditions may occur with forecasts such as occurred in the years 1973, 1983, and 1995. These were years in which spring spills were undetectable earlier in the winter/spring and which would result in BHBF's or spills later in the runoff year. The timing of such releases may occur in the March or April time frame, but also could occur later in the runoff season.

Previous presentations to the AMWG and the TWG have addressed the use of forecast risk curves as a means for triggering BHBF's. However, the subgroup felt this approach to be too complex. The substitution of the forecast percent of normal and 1.5 MAF monthly release volume as thresholds are actually similar measures of forecast risk.

The subgroup recognizes that these trigger mechanisms will initiate BHBF's in months other than the months of March and April which have been targeted previously for such flows. However, the long term frequency of BHBF's is greatly dependent on an ability to recognize statistically extreme events such as much above normal snowpack conditions early in the year or the potential for large spring precipitation events that result in large increases in the forecast late in the runoff period. The proposed triggering mechanisms attempt to (1) comply with the Secretary of the Interior's commitment made in the GCDEIS ROD, (2) minimize the number of actual spill years that were not recognized in time for a BHBF in March, and (3) minimize the number of years in which BHBF's were triggered but in which an actual spill did not materialize.

5 - For the following three paragraphs, the statistical results of the model runs apply to conditions only when the reservoir is at the target content of 21.5 MAF on January 1. As a long term average, ~~this full~~ condition is expected to occur about half the time in the future. Therefore, the <u>long term</u> frequency of spills and BHBF's (1 year in 6) is about half of the <u>modeled</u> frequency (1 year in 3). Table 1 compares the proposed vs. current occurrences of spills and BHBF's.

Modeled Frequency

Under an aggressive operating strategy, the modeled frequency of unavoidable spills is 4 years out of the 32 years modeled. However, since Lake Powell has not completely filled since 1986 and there have been recent concerns about making such very high releases, Reclamation has moderated the aggressiveness of the monthly release pattern. Under the existing, more moderate strategy, the modeled frequency of such spills is 5 years out of the 32 years modeled. By additionally restricting January releases to 1.2 MAF, this modeled frequency increases to 6 spill years out of the 32 years modeled. We expect that with the implementation of the measures described above, an additional 4 years in the model period would be determined to be BHBF years even though an unavoidable spill did not eventually occur, resulting in a combined total of 10 spill and BHBF years out of 32 years modeled.

Long Term Frequency

The result is that when the reservoir is full, there is a relatively high likelihood (1 year in 3) that a spill or BHBF will occur. On a long term basis, this proposed approach will result in a spill and BHBF frequency of about 1 year in 6. Of course, the appropriateness of this frequency would be dependent on a careful evaluation of all affected resources, a long term sediment balance analysis, and concurrence on the release of a BHBF in months other than March or April. Of this last contingent, months later than April are the more likely scenario due to late season forecast increases, but also could occur prior to March if the snowpack and resulting runoff forecast are unusually large.

If the above or similar recommendations are adopted, the frequency of spills and BHBF's created by deliberate bypasses of the powerplant will approximately double, and increase the hydrologic dynamics believed to enhance the Grand Canyon ecosystem. This may serve in part to offset the impacts thought to be the result of daily fluctuating flows. As a way to compensate for decreased power generation revenues due to the increased frequency of powerplant bypasses, and to evaluate the effects of fluctuating flows in combination with the effects of increased frequency of spills and BHBF's, we recommend that Reclamation and the Western Area Power Administration be instructed to operate the powerplant with the full range of fluctuations now provided for in the GCDEIS Record of Decision.

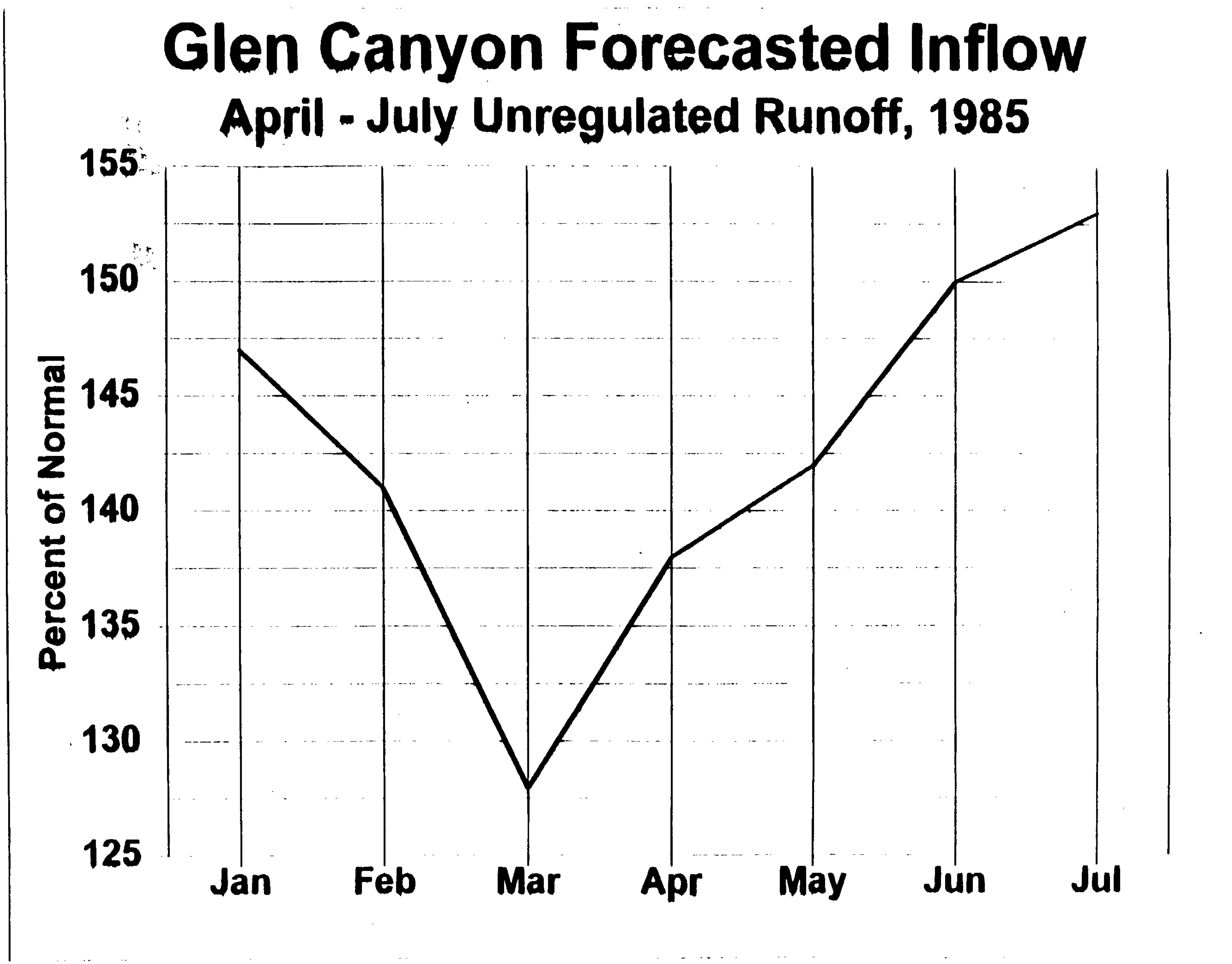
Recommendations for Additional Economic and Environmental Resource Studies

Since some have suggested a linkage between BHBF's and fluctuating releases, we recommend that the GCMRC be instructed to develop and initiate a program of research to evaluate the scientific and economic impacts of fluctuating flows within powerplant capacity in conjunction with the increased frequency of spills and BHBF's.

There is a also a strong need for resource evaluations respecting the proposed increase in spills/BHBF frequency. The resource relationship between BHBF's and high powerplant releases should be thoroughly investigated. Additional discussions should determine if this is indeed beneficial from a resource point of view or if high powerplant releases should occur without a BHBF, knowing that the risk of an unavoidable spill may be quite high in some years.

The timing of these decisions is also important from a resource perspective. In the past, the period of late-March to early-April was identified as the most appropriate time for a BHBF. However, from our analysis, it is clear that such a small decision window severely limits the ability to identify hydrologic conditions which meet the intent of the agreement contained in the 1996 AOP. Thus the two trigger mechanisms described above provide additional opportunity to adjust operational releases in response to runoff forecasts while also scheduling BHBF's which protect and enhance sediment conditions as well as other Grand Canyon resources. These resource discussions should address the impacts of a BHBF and an uncontrolled spill later in the same year, a BHBF prior to March if the January - July runoff forecast is greater than 13 MAF, a pre-emptive BHBF after April if the forecast increases, and an unavoidable spill as Lake Powell storage reaches its peak in July without first having a BHBF.

In order to implement these proposed BHBF trigger criteria, we also recommend to the TWG that any required National Environmental Policy Act compliance or Endangered Species Act compliance be initiated immediately. This will allow the AMWG to consider the implementation of this criteria at the beginning of the 1998 runoff season.


Glen Canyon Forecasted Inflow
April - July Unregulated Runoff, 1985
Percent of Normal
155
150
145
140
135
130
125
Jan
Feb
Mar
Apr
May
Jun
Jul

Glen Canyon Forecasted Inflow

April - July Unregulated Runoff, 1972

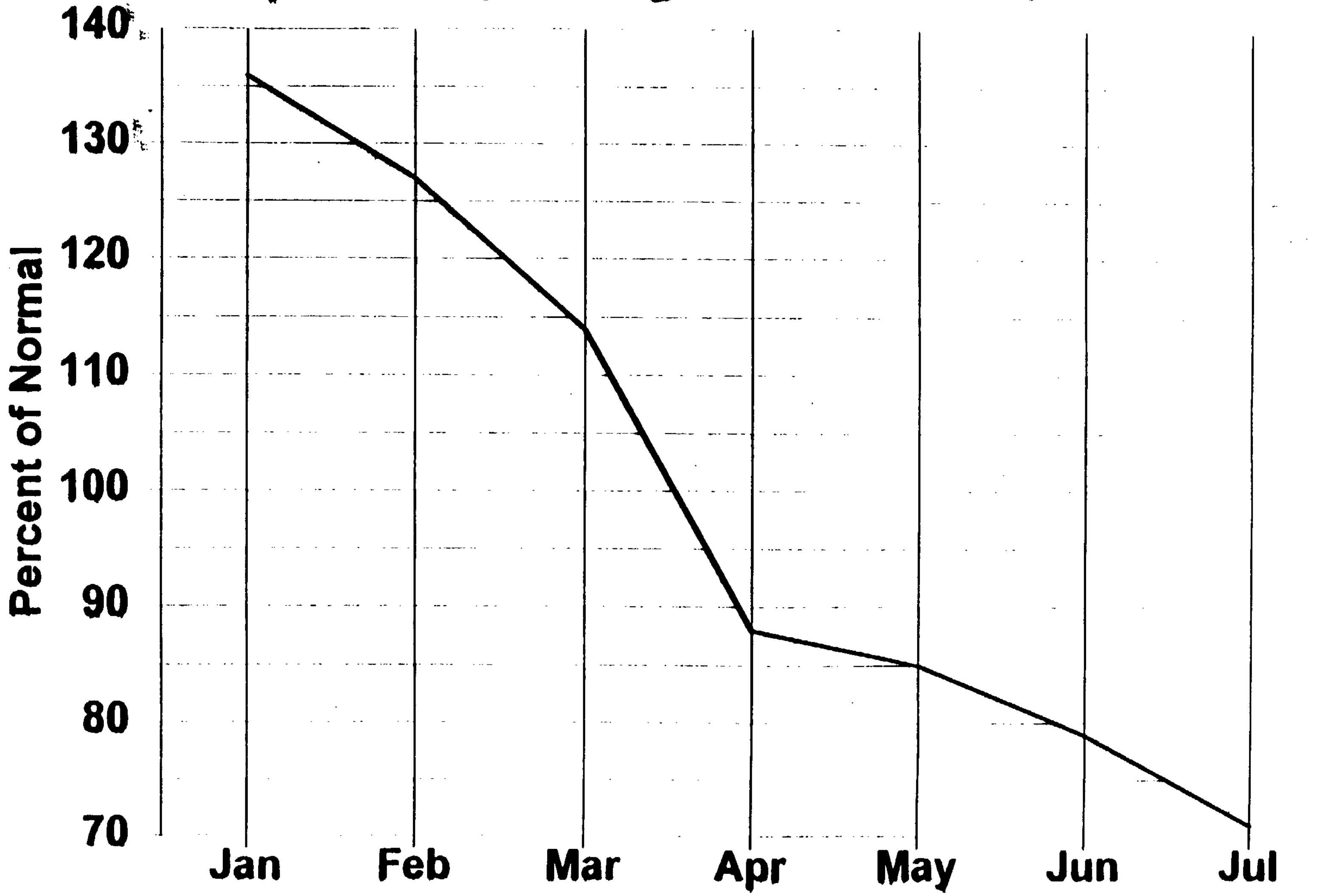


Table 1	Aggressive Operating Practice	Current Operating Practice	Proposed BHBF Triggering Criteria (with 1.2 MAF January release constraint)	
	Month of Actual Spills	Month of Actual Spills	Month of Actual Spills	Month of BHBF or Actual Spill
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973	June / July	June / July	June / July	June / July
1974				
1975				
1976				
1977				
1978				
1979				March
1980				June
1981				
1982				
1983	June / July	June / July	June / July	June
1984	June / July	June / July	May / June / July	January
1985		June	June	January
1986			May	March
1987				
1988				
1989				
1990				
1991				
1992				
1993				March
1994				
1995	July	June / July	June / July	June
1996				
1997				January

Appendices

Attached are the modeling analyses used to investigate the modification of current operating practices. These analyses cover the modeled period 1966 through 1997, and are organized according to the following assumptions:

Analysis #	Initial January 1 Storage (MAF)	July 31 Target Storage (MAF)	Degree of Aggressiveness in Avoiding Spills	# Unavoidable Spills
1	21.5	23.8	Aggressive	4
2	21.5	23.8	Moderate (current)	5
3	21.5	23.8	Moderate, restricting January releases to 1.2 MAF (Proposed)	6*

* This is the analysis upon which additional BHBF triggering mechanisms were based. Using the proposed BHBF triggering criteria, an additional 4 BHBF years would occur in the modeled period, resulting in a total of 10 years out of 32 years modeled in which spills or BHBF's would occur.