Estimated Effects on Downstream Resources from Short Duration (2-4 days), 45,000 cfs releases from Glen Canyon Dam, Between the Months of January to July

Introduction

Weather conditions conducive to higher than normal spring run-off in the Upper Colorado River Basin are predicted for 1998. In light of potential high inflows to Lake Powell, the Adaptive Management Work Group is examining alternative hydrograph scenarios for Glen Canyon Dam for the months of January through June. One scenario involves a "beach/habitat building" flow (BHBF) at a discharge of up to 45,000 cfs for 2-4 days. The Grand Canyon Monitoring and Research Center (GCMRC) has been requested by the Adaptive Management Work Group (AMWG) to evaluate the effects of short duration, sustained high flows on downstream resources for these months. The resources of concern are the biological, physical, and cultural/socioeconomic resources located between the forebay of Glen Canyon Dam and the western boundary of Grand Canyon National Park.

Program managers from the GCMRC canvassed researchers familiar with these downstream resources and asked them evaluate the potential effects (+3 strongly positive to -3 strongly negative) of this flow on resources for the months of January to July. The researchers were required to provide literature that supported their estimates. Attempts were made to have several researchers provide input for each identified resource and these data were subsequently consolidated. Therefore estimated effects on single resources represent an average of all contributing researchers' views.

The following is a summary of the estimated effect on resources subjected to a short duration, 45,000 cfs flow. Average values for each resource were recorded (Table

1) and graphed (Figs. 1,2) for each month. A second interation process involved providing the researchers with the initial results and asking for their comments and provided an opportunity to refine their scores (Table 2). For each month, a narrative highlights the resources identified as potentially negatively impacted by this flow. The degree of negative impact ranges from values that are less than -1 to values of -3. Values in the resource matrix (Table 1) represent averages and the "N" is the number of respondents who provided input for that resource. Values of "0" for a particular month represent no impact and do not appear graphically, although the resource may be included on the legend in figures 1 and 2.

A review of the matrix suggests that some resources are negatively impacted during any month by a short duration high flow. This result is expected for some resources because floods are a natural force capable of moving sediment, rocks, boulders, trees and generally disrupting processes. Floods are a natural part of the Colorado River System and the intent of the Beach Habitat Building Flow in the EIS was to return some of this dynamic to the system. The immediate effects of a flood on a resource may be negative (e.g., scouring out marsh plants), but the recovery and rate of response can compensate for the immediate negative impact. Other resources may have immediate positive affects. Rate of recovery or impact is affected by flows that follow a flood event. The high steady flows that followed the 1996 BHBF were beneficial to growth and colonization rates of some biological resources (Kearsley and Ayers 1996; Shannon et al 1997), but these subsequent flows also increased erosion rates of beach areas that showed an immediate positive response to flooding (Kearsley and Quartaroli 1997; Thompson et al 1997). When planning high flows in high water years, a caveat should be to consider the anticipated discharge rate that follows the high release.

The following provides a listing of resources of concern by month, the comments and concerns voiced by researchers that participated in this effort the resulting first and second matrix, and the literature citations that were provided by the researchers for each resource. These citations and the results from the matrix survey represent an initial attempt and a second iteration at determining the effects of a short duration high flow on downstream resources for months of January to July.

II. Resources of Concern by Month

January - Resources that are shown to have an negative effect in January include: fishing, over wintering birds, bald eagles, waterfowl, Southwestern Willow Flycatcher (SWWF) habitat, Kanab Ambersnail (KAS), humpback chub, flannelmouth sucker and trout spawning, larval and juvenile trout survivorship, and economic costs. Estimated negative impacts for these resources range from -0.3 for native fish spawning and -1 for bald eagles to -1.4, -2, and -2.5 for fishing, trout spawning, and KAS.

Concerns associated with those resources that have impacts greater than -2 (i.e., approaching -3 values) are: U.S. Fish and Wildlife Biological Opinion Statements that prohibit 45,000 cfs flows until one other KAS population is established or discovered in Arizona, and the loss of KAS individuals in habitats below 45,000 cfs stage at Vaseys Paradise. Flows of 45,000 inhibit recovery of KAS habitat and kill ambersnails that reside within the discharge zone (Meretsky pers.com). See comments below. Rainbow trout spawning in the Glen Canyon Reach begins in mid-November and continues through mid-March, and high flows in January would affect larval and juvenile fish either by dispersal of small fish downstream, stranding during the downramping or through predation. Associated with trout is the fishing industry at Lees Ferry. January is a month within the prime trout fishing season (October - May), and a 45,000 release would result in days of lost revenue to fishing guides. Bald eagles are also negatively impacted in January (-1). Sand in the channel bed would be lost at 45,000 cfs, but this sediment would stored to some extent in sandbars and channel margin deposits, if the flow was of short duration. Otherwise, high sustained flows from 20k - 30k cfs, or higher will result in a loss of this resource.

February - Negative impacts in February are those already noted for January with the addition of impacts to riparian habitat (-1) and overwintering birds (-2). Impacts diminish slightly in February for trout spawning decreasing from -1 to -0.5. Concerns for KAS increase to -2.2.

March - Resource effects remain slightly negative for native fish spawning. Trout survivorship remains a concern, and March is shown as having a most negative impact for fishing, changing from -1.4 to -2. Concerns about the risk of tamarisk germination (-1) begin in March, as well. Breeding birds become more impacted by March flows (-1).

April - Negative impacts are associated with more biological resources including larval and juvenile age-classes for native fish (HBC larval = -0.3), riparian habitat (-1.5) and SWWF habitat (-0.4), and the probability for tamarisk germination increases (-0.6 to -1.3). Avifauna are estimated to become more affected by flows in April (waterfowl -2.5).

May - High flows in May are estimated to slightly affect marsh and woody plants, and have a greater negative impact on riparian habitats (-2). Cultural resources are estimated to be slightly negatively impacted from May through July. Day rafting becomes more impacted (-1 to -1.3). Native fish spawning and survivorship of larval and juvenile stages are also increasingly negatively affected.). An additional resource that becomes negatively affected in May is the aquatic food base.

June - Greatest resource impacts from a high flow in June are on breeding birds, native fish larval and juvenile stages (HBC larval =-2.6; FMS larval = -0.75; juvenile = -0.25) and a continued concern about tamarisk seedling germination (-1.6).

July - Resources affected by a high flow in June remain affected by July high flows. Additionally, native and non-native fish habitat become negatively affected by high flows in July.

III. Comments regarding the Effects Matrix

The number of resources considered (45) and the lack of prioritizing or weighing of these resources.

There is no apparent pattern or indication of a better time to have a high release because the number of variables considered is too high and all variables are weighed equally. The original intent of the BHBF was to rebuild high elevation sandbars, deposit nutrients, restore backwater channels and provide some of the dynamics of a natural system. Examining the matrix with respect to these resources indicated that a flood anytime for the period between January and July would benefit sandbars, provided there was sufficient sediment in the system. To some extent nutrient cycling would also benefit. However, results from researchers indicate that the magnitude of the BHBF was not sufficient for backwater rejuvenation (scouring) or to reset successional clocks associated with riparian/shoreline habitats. Recommendations for subsequent BHBF were for higher magnitude releases (>55K), shorter duration (2-4 days) and that they be timed to sediment input from major tributaries.

Variables that add to the decision-making process associated with high releases include endangered species and other biological considerations, cultural resource impacts and economic impacts. Of these areas, the biological resources are the most variable in their response to the timing of a high release. The biological resources are also those variables that are most affected by subsequent release patterns (e.g., flucuating vs steady high flows). If the intent of the BHBF remains the same, then the Technical Work Group and the Adaptive Management Work Group needs to determine which variables beyond sediment availability and water storage capacity should have more weight in the timing of these flows (i.e., what is being managed for?).

"A priority of resources needs to be derived based on the current legislation, which puts endangered animals and archeology sites at the top. All others are a distant second. This drainage is headed in the same direction as the Upper Colorado Basin and the Columbia Basin where the fish are being lost due to the process being more important than the product (Shannon, pers com)."

The scale that was provided (+3 - -3) was too vague and open to broad interpretation.

This is a valid concern. A +3 could be interpreted as being permanently beneficial for a resource, and a -3 could be interpreted as the total destruction of a resource. In contrast, these values could be interpreted as the best or worst action that could be taken at that time. Some researchers did not realize that half-points could be used. Lacking this information may have resulted in a slightly higher or lower rating for a resource. An aspect of ballot stuffing, or a popularity contest was suggested by a respondent in that a researcher could provide scores that favored a month over others by inflating their scores. The information provided by the researcher that supported his/her rating should have diminished this affect.

Consideration in timing needs to include subsequent estimated release patterns.

The high steady flows that followed the BHBF in 1996 promoted growth and productivity in vegetation (Kearsley and Ayers 1997) and recovery of the aquatic food base. The latter may have been influenced by an increase in the available area and consistent area available for colonization associated with high, steady volumes. The optimum light conditions due to a lack of sediment input (Shannon et al. 1997) also likely benefited the aquatic food base. Both of these parameters and their responses to subsequent releases have ramification for other resources such as shoreline and riparian habitat, campable beach areas, and associated recreational/economic resources. Recognizing resources that respond to long-term management regimes, such as the aquatic food base and vegetation, and managing for those resources that directly and indirectly influence economic and cultural resources in this system, may help define the impacts of the timing of a BHBF during the months of January to July.

Changes in any of the values associated with the matrix

There was little additional response to the matrix (see table 2) when it was returned to researchers. More explanation was provided for the Kanab ambersnail rating (see below), with the result being that the ambersnail would be more consistently negatively impacted (2.4-2.6) for all months. Slight positive changes were expressed for marsh and woody vegetation, but these values did not change greatly: the effects were still estimated to be between -.5 and +.5 for all months. Avifaunal estimates also changed. The value for waterbirds shifted more negatively from -.5 to -1 and -2 to -2.5. Breeding avifauna effects become more consistently impacted across months with a range of 0 for January and increasing negative values of -0.5 to -1.9 in May. Tamarisk germination was estimated to have slightly less likelihood of germination in later months (-1.6 vs -2.5).

There was too few numbers of respondents for this matrix to be very realistic or informative.

The matrix was sent to 48 researchers that were either associated with the previous Beach Habitat Building Flow, or associated with riparian and aquatic environments. Unfortunately, the response was not overwhelming. Several components may have contributed to this low response including: timing of this mailing (the middle of November); the lack of follow-up calling to remind people of the need for their input; the respondents were frustrated by the format of the matrix, and did not understand how to fill it out; or researchers felt that they could not afford to spend the time if they were not being compensated monetarily. Calling those researchers for which we had no response may encourage more responses. This will determine if the instructions for the matrix were vague, or if other reasons existed for his/her lack of response.

Some researchers suggested that a meeting would have been more productive. However, it is likely that a meeting would have resulted in fewer participants than a mailing due to funding constraints. Convening a meeting may be more productive when resources are prioritized, more responses are collected, and the purpose of the habitat flow is redefined or determined to remain as it is in the EIS.

Comments from researchers regarding specific resources

Kanab Ambersnail - The BHBF in 1996 removed by scouring ca 16% of KAS habitat at Vaseys Paradise. Habitat recovery has been slow and is estimated to take several years to re-establish. Complete mortality is assumed for snails that were within the path of the flood, since no populations have been found in subsequent seep and spring surveys. It is believed, based on fossil and subfossil records that *Oxyloma* in Arizona is not widely distributed and is not a good colonizer.

Recent genetic studies of four putative populations of Oxyloma Haydeni in Arizona and Utah suggest that the Vaseys Paradise may be genetically "unique". The effects of any perturbation on a federally listed taxon should be viewed in the extent to which its future existence is jeopoardized even withouth the additional insult. This is the part of the environmental baseline on which the action, in this case a controlled flood event must be judged.

It is not apparent that the magnitude of effect from a 45,000 cfs flood will vary from January - July. A differential rate of recovery of habitat in January vs July does not seem apparent based on current knowledge. Similarly, direct effects on the KAS population would likely not change for these months. Reproductive contribution to the next generation would likely not be different for a flood occurring in January versus one staged in July.

Conservative ranking in this case (i.e., overestimating effects) is more acceptable than underestimating. The exact rarity of the organism in unknown, and other environmental calamities/impacts could occur to this population, in addition to the controlled flood. To place at risk some portion of such a population is untenable.

Optional activities that risk snails or habitat at Vasey's Paradise are not acceptable (Kubly and Meretsky, pers. Com).

Riparian vegetation - There would likely be only the slightest impacts on marshes, especially since the proposed flow is for two days. Immediately after the flow there was a layer of buried herbs and grass observed, but most of the clonal herbaceous types in marshes wer back within six months to where there was very little difference from the same time the previous year. Total cover was down in the marshes, but the areal extent of marshes did not differ.

The significant impacts were on seed banks, where marsh polygons lost, on average 40% of their species and individuals (this is based on comparisons between February 1997 with February 1996). Other data indicates that these seed banks may be recovering rather quickly.

It is important not to confuse the effects of the flood with the effects of high constant summer flows. In 1996, the rapid recovery of vegetation was the result of high, near-constant discharges which created a high elevation water table that encourgaed plant growth. The high flows in 1997, without a flood, had a nearly identical impact to the point where total vegetative cover in the monitoring sites in now greater than it was in 1995. To attribute this beneficial effect to the flood is just wrong. Flood effects on plants will always be modified by later flows. (Kearsley, pers com).

Sediment/Sandbars - Data from the 1996 flood confirms that deposition occurs at the water's edge, but that substantial scour can occur offshore in the central part of large eddies. Data collected during the flood showed that depostion rates can be very high, and that some eddies can "overfill" with subsequent slumping of eddy sand bars into the main channel potentially occurring. The flood did not create substantially larger sand bars in the Point Hansbrough-Saddle Canyon reach, suggesting that sand concentrations are not sufficient to build large bars in this reach. Assess the differences in response between upper Marble Canyon and the rest of Grand Canyon may be more informative than assessing the differences in response between narrow and wide reaches.

High flows that immediately followed the 1996 flood contributed to the high post-flood erosion rates. Schmidt and Graf (1990) show that high rates of erosion always follow bar-deposition events, the extent of erosion will be determined by the magnitude, and thus the stage, of these flows.

Timing of release is of little concern to physical processes, except for forecast error and distribution of very fine sediment. The magnitude and duration of the flood is the primary question that needs to be addressed by the scientific community. The benefits of a high flood would be increased if the magnitude were greater than that which occurred in 1996. Deposits of 1996 have now sealed off many channel-margin settings. A repeat of the same stage will likely not inundate many channel-margin settings.

The essence of the pre-dam environment was variability. Flood magnitudes differed from year to year: no two years were ever the same. Repeated floods of the same magnitude build longitudinally-correlative benches along the river that did not exist prior to dam construction (Schmidt and Rubin 1995; Grams 1997). Reintroducing variability in magnitude is an important element need in the flood regime. A proposed release strategy would be to conservatively manage releases in winter and spring, bring the reservoir to near full pool, and rleaseing a very high flow in excess of 50,000 cfs in May or June (Schmidt pers. com).

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Enclosed is a summary of the estimated effects of a short duration, 45,000 cfs flow if it occurred in months January to July. This summary represents the results of the input provided to us from approximately one half of the researchers that were originally contacted. We appreciate the time and effort required by you to provide this information.

A review of the matrix suggests that resources are negatively impacted during any month by a short duration high flow. The estimated effects by researchers for some resources were highly variable (i.e., from 3 to -3 for a single month). And the estimated negative impacts for some resources run counter to results presented in the April Flood Symposium (summary enclosed). Included in this packet are individual responses for those resources that were estimated to be negatively impacted. The responses are represented by columns and the rows represent the months of January to July. We have also provided excerpts from abstracts concerning the results from the spike flow in 1996.

We would like you to review the summary and the responses, and provide us with your revised rankings, if any, as well as any additional comments and concerns. As before, we would like your comments to be supported by literature. Please try to make your citations more specific (i.e., describe the result in the citation that supports your viewpoint). Information provided in this manner can lead to a more complete and thorough synthesis of researchers opinions. We would like to have your comments back to us by **January 9, 1998**. Again you can fax or email your responses to Barbara Ralston at **(520) 556-7368**, or **bralston@sven.uc.usbr.gov**. Thanks again for your interest and responses.

Sincerely,

Barry D. Gold

Resources estimated at no impact

January

- Day rafting
- Riparian habitat
- Breeding birds
- Humpback chub larval-adult
- Flannelmouth sucker larval-adult
- Trout - adult
- Economic benefits
- Air quality
- Wholesale/retail rates

February

- Day rafting
- Native fish habitat
- Non-Native fish habitat
- Waterfowl
- Humpback chub larval-adult
- Flannelmouth sucker larval-adult
- Trout - adult
- Economic benefits
- Air quality
- Wholesale/retail rates

March

- Aquatic foodbase
- Humpback chub - juvenile,adult, spawning
- Flannelmouth sucker - adult
- Economic benefits
- Air quality
- Wholesale/retail rates

April

- Raptors/Bald Eagle
- Humpback chub adult, spawning
- Flannelmouth sucker adult
- Trout spawning
- Economic benefits
- Air quality
- Wholesale/retail rates

May

- Whitewater rafting
- Raptors/Bald eagles
- Overwintering birds
- Humpback chub - adults, spawning
- Flannelmouth sucker - adult, spawning
- Trout spawning
- Economic benefits
- Air quality
- Wholesale/retail rates

June

- Whitewater rafting
- Raptors/bald eagles
- Humpback chub - adults, spawning
- Flannelmouth sucker - adult, spawning
- Trout spawning
- Economic benefits
- Air quality
- Wholesale/retail rates

July

- Whitewater rafting
- Raptors/bald eagles
- Humpback chub - adults, spawning
- Flannelmouth sucker - adult, spawning
- Trout - juvenile, spawning
- Economic benefits
- Air quality
- Wholesale/retail rates

Range of scores for resources showing negative affects.

Fishing
-2, -2,
-2, -2
-3, -3
-2, -3
-2, -2
-1, -2
-1, -2

Kanab ambersnail
-1, -3, -3
-1, -3, -3
-1, -3, -3
-1, -3, -3
-2, -3, -3
-2, -3, -3
-2, -3, -3

Breeding birds
0, 0, 0
0, -1, 0
-1, -2, 0
-1, -3, 0
-2, -3, -.8
-3, -3, -.5
-3, -3, 0

Waterfowl
-1, 0. -1
1, 0, -1
-1, 0, -1
-3, -1, -2
-3, -2, -2
-3, -2, -2
-3, -2, 0

FMS spawning
0, -1
-1, -1
-2, 0
-2, 0
0, 0
0, 0
0, 0

Aquatic foodbase
0, 0, 0, 0, -3
0, 0, 0, 0, -3
-1, 0, 0, 2, -3
-1, 0, -1, 2, 3, -3
-1, 0, -1, 2, 3, -3
-1, 0, -2, 2, 3, -3
-1, 0, -3, 2, 3, -3
-1, 0, -3, 2, -3, -3

Marsh
0, 3, 0, -2, 3
0, 3, 0, -2, 3
-1, 3, -1, -2, 3
-2, 3, -1, -2, 3
-2, 3, -2, -2, 2
-2, 3, -2, -2, 1
-2, 3, -2, -2, 1

Riparian habitat
0, 0
0, -1
0, -1
-1, -1
-1, -2
-1, -2
-1, -2

Tamarisk Germination
1, 0
1, 0
-2,0
-3, -1
-3, -1
-3, -2
-3, -2

Trout larval
-2, -3, -2, 0
-2, -3, -2, 0
-2, -2, -1, -3
-2. -1. 0, -3
-2, [illegible], 0, -3
-2, 0, 0, -3

Trout juvenile
-1, -3, -2, 0
-1, -3, -1, 0
-1, -3, -1, -3
-1, -3, -1, -3
-1, -3, -1, -3
-1, -2, -1, -3
-1, -2, -1, -3

Trout adult
-1. 3. 0, -2
-1. 3, 0, -2
-1, -2, 0, -2
-1, -2, 0, 0
-1, -2, 0, 0
-1, -2, 0, 0
-1, -2, 0, 0,

HBC larval
0. 0, 0
0, 0, 0
-1, 0, 0
-2, -1, 0
-3, -2, -1
-3, -2, -3
-3, -1, -3

HBC juvenile
0, 0, 0
0, 0, 0
0, 0, 0
-1, 0, 0
-1, -1, 0
-1, -1, -1
-1, -1, -3

FMS larval
0, 0, 0, 0
0, 0, 0, 0
-1, 0, 0, -3
-2, -1, 0, -3
-2, -1, 0, -3
-3, -2, -1, -3
-3, -2, -2, -3
-3, -1, -3, -3

FMS juvenile
0, 0, 0, 0
0, 0, 0, 0
-1, 0, 0, 0
-1, 0, 0, 0
-1, -1, 0, 0

-1, -1, -1, -3

-1, -1, -2, -3

FMS spawning
0, -1
-1, -1
-2, 0
-2, 0
0, 0
0, 0
0, 0

Aquatic foodbase
0, 0, 0, 0, -3
0, 0, 0, 0, -3
-1, 0, 0, 2, -3
-1, 0, -1, 2, 3, -3
-1, 0, -1, 2, 3, -3
-1, 0, -2, 2, 3, -3
-1, 0, -3, 2, 3, -3
-1, 0, -3, 2, -3, -3

Excerpts from Symposium Abstracts

Habitat loss due to 45k
51.2 sq m remained after the flood. This includes 14.3 sq m of Mimulus and 14.1 sq m of Nasturtium.

Pre-flood estimates of habitat included 81.5 sq m of Mimulus and 48.4 sq m of Nasturtium. A total of 163.7 sq m of vegetated cover existed downslope from the estimated 45k = 1.5' stage. Observed levels are 157.2, 51.3 and 39.2 sq m respectively. 31.4% of pre-flood habitat remained in the flood zone. Estimated that 1% of vegetation was usable after the flow. (Meretsky and Stevens 1997)

Vegetation

Effects to extant vegetation were minor and limited to patches adjacent to river. Affected patches lost herbs, and herbaceous perennials due to burial (1.5m). No significant effect of the flood on adult weeds. Seed banks in all sites were severely affected--losing ca. 80% of individuals and 805 of species richness. Loss in variability of particle size of surface organics. Loss of seed banks should extend the effects of the flood on herbs and herbaceous species for several years especially in combination with changes insubstrate.
Effects below diamond creek include prolonged innudation in conjuction with Lake Mead water management. -(Kearsley and Ayers 1996)

Terrestrial avifauna

Mean individuals, species, ground gleaners and tree gleaners all declined significantly post-flood. Time of flood suggest that migration was unlikely to have been the cause of this decline. Loss of river edge habitat or reduction in the resource base (prey items, seed, fruits) that may have been swept away during the flood - (Spence 1996b)

Flannelmouth sucker

Staging by fms in late Feb, early March spawning in March and April in Paria. Adults were found in the innundated mouth of the paria during the flood and returned to the mainstem, post-flood. Spawning in the paria river proceeded as in non-flood years and was apprently successful--capture of 576 yoy in late spring and summer. Subsequent high flows provided rearing area for young fish. Spring flooding of magnitude of BHBF has no detrimental effect of spawning movement of fms. (Thieme and McIvor 1997)

Fish distribution, dispersal, habitat use

Few differences in fish distribution and abundance were seen before and after the flood. No significant decreases were seen in adult rainbow trout or in the HBC. Differences were seen among non-native fish regarding distribution and abundance (fathead minnows, plainskillifish, trout). Overall, small, non-native fishes may have been nagatively impacted by the flood flow (Leibfried abstract), A decrease in non-natives post-flood near LCR.. Mean CPUE of juvenile rainbow trout seined n backwaters increased significantly post-flood. Indicating downstream transport of trout, probably from local spawning aggregations like Nankoweap Creek.
Fish move to impounded tributary mouths and large recirculating eddies during the high flows. Movement of HBC was not significantly different pre and post flood. Habitat used remained similar to previous years.

Native fishes were unaffects by the high flows (Hoffnagle et al 1997).

Trout
Relative abundance did not differ prior to and week after flows. Five to eight months following the flood, abundace was comparable to previous years. Strong recruitment eight months later indicateds that the flood did not prevent successful spawning.

Results indicate that the spike discharge and loss of submerged macrophytes and lower amphipod benthic densities had no important negative impacts on the rainbow trout population (McKinney et al. 1997)

Aquatic food base

Spring 1996 spike flow discharge had a significant positive impact on the aquatic foodbase in the Colorado River.

Recovery was complete in one month for most sites. No tributary input and optimal light conditions allowed for quick recovery. A Spike Flood under wet conditions--el nino may not be positive. (Shannon et al. 1997)

Table 1

HIGH FLOWS (>POWERPLANT CAPACITY) EFFECTS ON COLORADO RIVER RESOURCES

SCALE: -3 = STRONG NEGATIVE IMPACT, 0 = NO IMPACT, 3 = STRONG POSITIVE IMPACT

RESOURCE CATEGORY	INDIVIDUAL COMPONENTS	MONTH JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY
WATER	Streamflows							
	Lake Powell Stratfication N=2	0.6	1	1.3	1.3	1	0.6	0.6
	Downstream Water Quality N=3	0.3	0.3	0.6	1.6	1.3	1.3	1.3
SEDIMENT	Riverbed sand N=2	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
	After 20 years							
	After 50 years							
	Sand bars N=3	2.5	2.5	2.5	2.5	2.75	2.75	2.75
AQUATIC RESOURCE	Aquatic food base N=5	0.6	0.6	0	0	-0.2	-0.4	-0.4
	Native Fish habitat N=3	0	0.4	0.5	0.3	0.3	0.3	-0.3
	Non-native fish habitat N=3	0.6	0	0.4	0.5	0.3	0.3	-0.3
	Humpback Chub Spawning N=2	-0.3	-0.3	0	0	0	0	0
	Larval N=3	0	0	-0.3	-1	-2	-2.6	-2.3
	Juvenile N=3	0	0	0	-0.3	-0.6	-1	-1.6
	Adult N=3	0	0	0	0	0	0	0
	Flannelmouth Sucker spawning N	-0.5	-1	-1	-1	0	0	0
	Larval N=4	0	0	-1	-1.5	-2.2	-2.5	-2.5
	Juvenile N=4	0	0	-0.25	-0.25	-0.25	-1.5	-1.75
	Adult N=4	0	0	0	0	0		0

RESOURCE CATEGORY	INDIVIDUAL COMPONENTS	MONTH JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY
AQUATIC RESOURCES								
	Trout							
	Spawning N=1	-2	-1	-1	0	0	0	0
	Larval N=4	-1.75	-1.75	-2.25	-2	-1.5	-1.25	-1.25
	Juvenile N=4	-1.5	-1.25	-2	-2	-1.5	-1.5	-1.5
	Adult N=4	0	0	-0.25	-1.3	-1.3	-1.3	-1.3
VEGETATION								
	Emergent marsh plants N=4	0.6	.06	0.25	0.12	-0.37	-0.6	-0.6
	Woody Plants N=4	0.12	0.12	0.12	-0.12	-0.6	-0.6	-0.6
	Preventing Tamarix Germ'n N=3	0.5	0.5	-1	-2	-2	-2.5	-2.5
WILDLIFE & HABITAT								
	Riparian habitat N=2	0	-0.5	-0.5	-1	-1.5	-1.5	-1.5
	Waterbirds N=3	-0.6	0	-0.6	-2	-2.3	-2.3	-1.6
	Terrestrial Invertebrates							
	Breeding birds N=3	0	-0.3	-0.6	-2	-1.85	-2.17	-2
	Overwintering birds N=3	-1	-1	-1	-0.5	0.5	0	0
LISTED & SPECIAL STATUS SPECIES	Bald Eagle/Peregrine Falcon N=3	0	-0.5	-0.5	-1	-1.5	-1.5	-1.5
	Kanab Ambersnail+Habitat N=3	-2.3	-2.3	-2.3	-2.3	-2.6	-2.6	-2.6
	SW Willow Flycatcher+Habitat N=	-0.17	-0.17	-0.17	-0.5	-0.5	-0.8	-1
CULTURAL-SOCIO. RESOURCES	Archeological sites N=2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Traditional cultural properties N=;	1.5	1.5	1.5	1.5	0	0.5	1
	Traditional cultural resources N=:	0.6	0.6	0.6	0.3	-0.3	-0.3	-0.3
AIR QUALITY	Regional air quality N=1	0	0	0	0	0	0	0
RECREATION	Fishing N=2	-2	-2	-3	-3	-2.5	-2	-1.5
	Day rafting N=3	0	0	0.3	0	-1.3	-1.3	-1.3
	Whitewater boating N=3	1.5	1.5	1.25	0.5	0	0	0
	Economic benefits N=1	0	0	0	0	0	0	0
POWER	Annual economic costs N=1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
	Wholesale rate N=1	0	0	0	0	0	0	0
	Retail rate N=1	0	0	0	0	0	0	0
	ALL RESOURCES	-5.2	-4.95	-10.9	-17.65	-23.22	-26.97	-27.05

Table 2 - 2nd Iteration

HIGH FLOWS (>POWERPLANT CAPACITY) EFFECTS ON COLORADO RIVER RESOURCES

SCALE: -3 = STRONG NEGATIVE IMPACT, 0 = NO IMPACT, 3 = STRONG POSITIVE IMPACT

RESOURCE CATEGORY	INDIVIDUAL COMPONENTS	MONTH JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY
WATER	Streamflows							
	Lake Powell Stratfication N=2	0.6	1	1.3	1.3	1	0.6	0.6
	Downstream Water Quality N=3	0.3	0.3	0.6	1.6	1.3	1.3	1.3
SEDIMENT	Riverbed sand N=3	0.16	0.16	0.16	0.16	0.16	0.16	0.16
	After 20 years							
	After 50 years							
	Sand bars N=4	2.6	2.6	2.6	2.6	2.8	2.8	2.8
AQUATIC RESOURCE	Aquatic food base N=5	0.6	0.6	0	0	-0.2	-0.4	-0.4
	Native Fish habitat N=3	0	0.4	0.5	0.3	0.3	0.3	-0.3
	Non-native fish habitat N=3	0.6	0	0.4	0.5	0.3	0.3	-0.3
	Humpback Chub Spawning N=2	-0.3	-0.3	0	0	0	0	0
	Larval N=3	0	0	-0.3	-1	-2	-2.6	-2.3
	Juvenile N=3	0	0	0	-0.3	-0.6	-1	-1.6
	Adult N=3	0	0	0	0	0	0	0
	Flannelmouth Sucker spawning N	0.25	0	0	0	0.5	0.5	0.5
	Larval N=5	0.5	0.5	0	-0.25	-0.6	-0.75	-0.75
	Juvenile N=4	0.5	0.5	0.37	0.37	0.37	-0.25	-0.37
	Adult N=4	0.5	0.5	0.5	0.5	0.5	0.5	0.5

RESOURCE CATEGORY	INDIVIDUAL COMPONENTS	MONTH JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY
AQUATIC RESOURCES								
	Trout							
	Spawning N=2	-1	-0.5	-0.5	0	0	0	0
	Larval N=5	-0.87	-0.87	-1.12	-1	-0.75	-0.62	-0.62
	Juvenile N=5	-0.75	-0.62	-1	-1	-0.75	-0.75	-0.75
	Adult N=5	0	0	-0.12	-0.65	-0.65	-0.65	-0.65
VEGETATION								
	Emergent marsh plants N=4	0.25	0.25	-0.25	-0.25	-0.75	0	0
	Woody Plants N=4	0.37	0.37	0.37	0	-0.5	-0.5	-0.5
	Preventing Tamarix Germ'n N=3	0.3	0.3	-0.6	-1.3	-1.3	-1.6	-1.6
WILDLIFE & HABITAT								
	Riparian habitat N=2	-0.5	-1	-1	-1.5	-2	-2	-2
	Waterbirds N=2	-1	-1	-1	-2.5	-2.5	-2.5	-1.5
	Terrestrial Invertebrates							
	Breeding birds N=2	0	-0.5	-1	-1	-1.9	-1.75	-1.5
	Overwintering birds N=2	-2	-2	-2	-1	-1	0	0
LISTED & SPECIAL STATUS SPECIES	Bald Eagle N=3	-1	-1	-0.6	0	0	0	0
	Peregrine Falcon N=2	0	0	0	0	0	0	0
	Kanab Ambersnail+Habitat N=5	-2	-2.2	-2.4	-2.4	-2.6	-2.6	-2.6
	SW Willow Flycatcher+Habitat N=	-0.2	-0.2	-0.2	-0.4	-0.4	-0.6	-0.6
CULTURAL-SOCIO. RESOURCES	Archeological sites N=2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Traditional cultural properties N=;	1.5	1.5	1.5	1.5	0	0.5	1
	Traditional cultural resources N=3	0.6	0.6	0.6	0.3	-0.3	-0.3	-0.3
AIR QUALITY	Regional air quality N=1	0	0	0	0	0	0	0
RECREATION	Fishing N=3	-1.4	-1.4	-2	-2	2	-1.4	-1
	Day rafting N=4	0	0	0	0	-1	-1	-1
	Whitewater boating N=5	1.4	1.4	1.2	0.6	0.2	0.2	0.2
	Economic benefits N=1	0	0	0	0	0	0	0
POWER	Annual economic costs N=1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
	Wholesale rate N=1	0	0	0	0	0	0	0
	Retail rate N=1	0	0	0	0	0	0	0
	ALL RESOURCES	-0.165	-0.61	-3.99	-6.82	-10.37	-14.11	-15.73