Glen Canyon Dam Adaptive Management Work Group
Agenda Item Information
December 5-6, 2006

Agenda Item

Grand Canyon Monitoring and Research Center Experimental Research Update

Action Requested

√ Information item only; no action is requested.

Presenters

Ted Melis, Deputy Chief, Grand Canyon Monitoring and Research Center
Matthew Andersen, Biological Resources Program Manager, Grand Canyon Monitoring and Research Center

Previous Action Taken

√ By AMWG:
The AMWG adopted a motion in April 2002 on an experimental plan that included a provision for "twice-a-year evaluation of data by AMWG."

Relevant Science

√ The following describes the relevant research or monitoring on this subject:
The relevant science is presented below.

Background Information

Our presentation will include updates on the following experimental research from the 2002 plan:

1. **Mechanical removal**

2. **Translocation of humpback chub above Chute Falls of the Little Colorado River**

No humpback chub were captured and moved (translocated) above Chute Falls on the Little Colorado River in 2006. In previous years a total of just under 1200 humpback chub have been translocated above the falls. In 2006, 313 humpback chub were captured above Chute Falls; of those, 105 were known to have been translocated. The next lower barrier on the Little Colorado River is Lower Atomizer Falls. Humpback chub are being monitored between these two barriers. In 2006, 456 humpback chub were captured in this reach, including 22 translocated fish and 53 that had moved up from below Lower Atomizer Falls. The capture of young of year humpback chub suggests that spawning is occurring above Lower Atomizer Falls, and possibly above Chute Falls. The growth rates of humpback chub captured above Chute Falls was relatively high in 2006.

3. **Aquatic food base and the carbon budget for the system.**

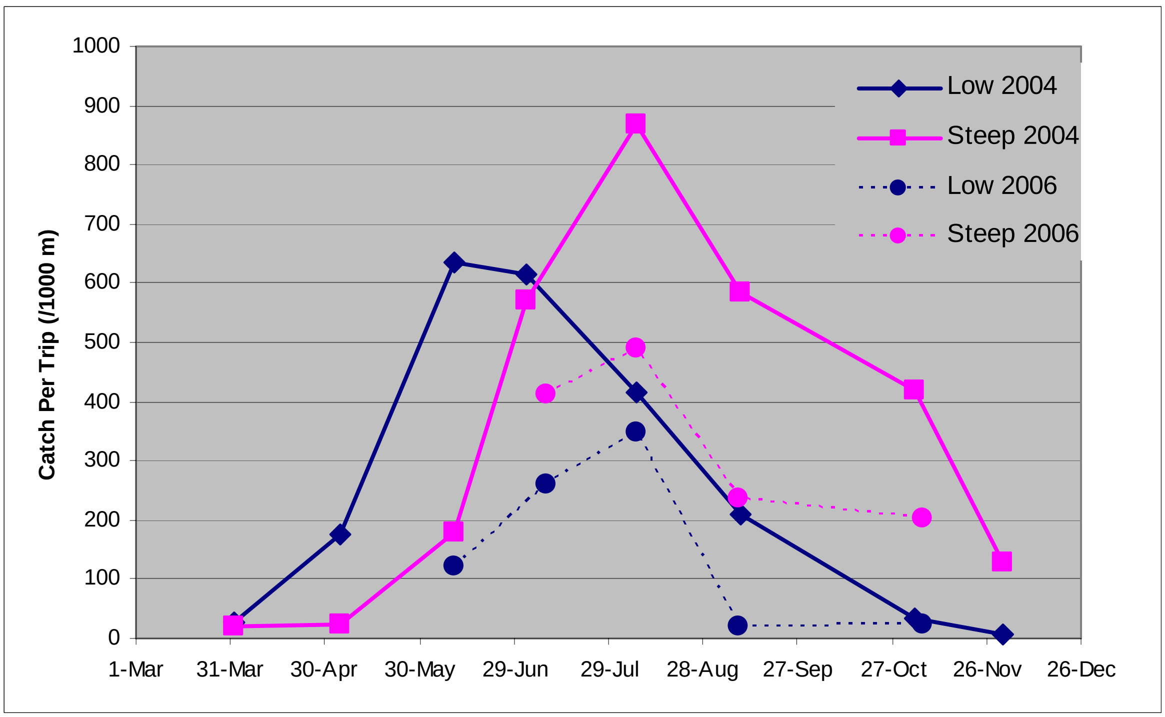
4. Rainbow trout spawning and reproduction

In 2006 the redd (rainbow trout nest) count in the Glen Canyon/Lees Ferry reach of the Colorado River was only 5% of that observed in 2004. The number of young of year rainbow trout in 2006 was about 50% of the population observed in 2004, strongly suggesting that individual fish are surviving better in 2006. Fishery scientists refer to this as a compensatory response.

The ratio of redds to young of year fish in 2004 versus 2006 suggests that the strong compensatory survival response of early life stages of rainbow trout may limit the effects of reducing incubation survival rates on adult population size via increases in fluctuating flows. This is a preliminary conclusion as the very limited egg deposition in 2006 confounds our ability to separate the effects of flow fluctuations (ROD vs. 5-20 kcfs) from the effects of reduced density due to limited spawning. Monitoring spawning intensity and age-0 abundance in a year with normal spawning levels under ROD flows would help resolve this uncertainty.

Young rainbow trout densities in low angle habitats in 2006 were very low by November, similar to the finding for 2004. Fish originally found in low angle habitats have both died and moved to steeper habitats were more drifting food is available.

Rainbow trout densities in steep angle habitats in 2006 are quite different when compared to 2004 results. In 2004 about one third of the population died or was otherwise lost from the system in the period from September to November. Over the same period in 2006 the population was relatively stable.



5. **Update on Results of the 2004 BHBF experiment**

Results from the 2004 controlled-flood experiment indicate that substantial increases in total eddy-sandbar area and volume in the Colorado River in Marble and Grand Canyons are possible only during controlled floods conducted under the sediment-enriched conditions that follow large tributary floods. Results from the 1996 controlled-flood experiment indicate that, during sediment-depleted conditions, sand deposited at higher elevations in downstream eddy sandbars is derived from the lower-elevation parts of upstream sandbars. Thus, controlled floods conducted under these conditions result in decreases in total eddy-sandbar area and volume (especially in Marble Canyon). Analysis of surveys conducted one to four times per year during the 1990s indicates that sandbars in Marble Canyon and the upstream part of Grand Canyon contained ~25% less sand at lower elevations in 2000 than in 1991, and that the lower-elevation parts of these sandbars and the adjacent channel bed never fully recovered in sand volume after scouring during the 1996 flood (Schmidt et al., 2004). Thus, controlled floods conducted under sediment-depleted conditions, such as those that existed in 1996, cannot be used to sustain sandbar area and volume. Under the lower dam releases that preceded the 2004 flood, most of the new tributary-supplied sand was retained in the uppermost part of Marble Canyon. During the 2004 flood, this sand was eroded from the channel bed and transported downstream, with a fraction transferred into eddies. This resulted in a net increase in the total area and volume of eddy sandbars in the upstream half of Marble Canyon. In addition, about half of the sandbars surveyed in this reach following the 2004 flood were substantially larger at higher elevations than they were following the 1996 flood. Downstream reaches were not as enriched with new tributary-supplied sand, however. During the 2004 flood, sand concentrations in Grand Canyon were lower than they were during the 1996 flood. The total area and volume of eddy sandbars downstream from about river-mile 42 generally decreased during the 2004 flood. Only 18% of the sandbars surveyed following the 2004 flood between river-miles 42 and 87 were larger at higher elevations than they were following the 1996 flood. Therefore, the amount of new sand in retention prior to the 2004 controlled flood was sufficient to result in substantial increases in sandbar area and volume in only the first 50 km of the 400-km long reach of the Colorado River in Marble and Grand Canyons. Only a relatively small amount of the new tributary-supplied sand in retention prior to the flood was deposited in the upstream half of Marble Canyon during the 2004 flood, resulting in the observed increases in total eddy-sandbar area and volume in this reach. Lengthening the hydrograph of a future controlled flood with a similar amount of sand as the 2004 flood, thus, would likely drive the sediment budget in the upstream half of Marble Canyon negative, resulting in either no change or a decrease in total eddy-sandbar area and volume. Therefore, in future controlled floods, more sand is required to achieve increases in the total area and volume of eddy sandbars throughout all of Marble and Grand Canyons. Annual tributary inputs of sand much larger than one million metric tons occur, but are relatively rare. Therefore, "more sand" could be achieved directly by augmentation from sand trapped in the reservoir impounded by Glen Canyon Dam or perhaps indirectly by following each large tributary input of sand with short-duration controlled floods. Frequent short-duration controlled floods under sand-enriched conditions could result in the downstream propagation (into the downstream half of Marble Canyon and into Grand Canyon) of the gains in total eddy-sandbar area and volume observed in the upstream half of Marble Canyon during the 2004 controlled-flood experiment.

6. **Update on recent tributary sediment inputs, current sand supply in the main channel (see background under #5, above, and the attached October 19, 2006 memo by Rubin and others), and status of BHBF science planning**

United States Department of the Interior

U. S. GEOLOGICAL SURVEY

Memorandum

To: John Hamill, Chief, Grand Canyon Monitoring and Research Center

From: Dave Rubin, David Topping, Scott Wright

Subject: Status of sand mass balance in the Colorado River ecosystem below Glen Canyon Dam

Date: October 19, 2006

Summary

Recent floods on the Paria River and Little Colorado River have supplied large quantities of sand to the mainstem Colorado River downstream from Glen Canyon Dam. Sand deliveries of such large magnitude occur on average only every five years, and the October 6, 2006, flood was the largest on the Paria River since 1998. Resource managers now have the relatively rare opportunity of exploiting this large quantity of sand for both habitat restoration and additional scientific learning.

Background

The most important science question identified by sediment scientists and managers at the 2005 Knowledge Assessment Workshop (KAW) was:

Is there a "flow-only" operation that will restore and maintain sandbar habitats over decadal timescales?

One significant outcome of the 2005 Knowledge Assessment conducted by the GCMRC was that, despite the great deal of learning that has occurred regarding sediment transport, sand bars, and dam operations in this system, the information and models are not yet capable of answering this question. The question can only be answered through a program that utilizes rigorous experimental floods whenever triggered by the specified amounts of new sand. The rationale for conducting experimental floods under sediment-enriched conditions has been documented in several peer-reviewed outlets, including Webb and others (1999), Topping and others (2000), Rubin and Topping (2001), Rubin and others (2002), Schmidt and others (2004), Wright and others (2005), Hazel and others (2006), Topping and others (2006), and by Randall and others (written communication). The flow chart below was developed at the KAW to guide experimentation toward answering the sediment science question:

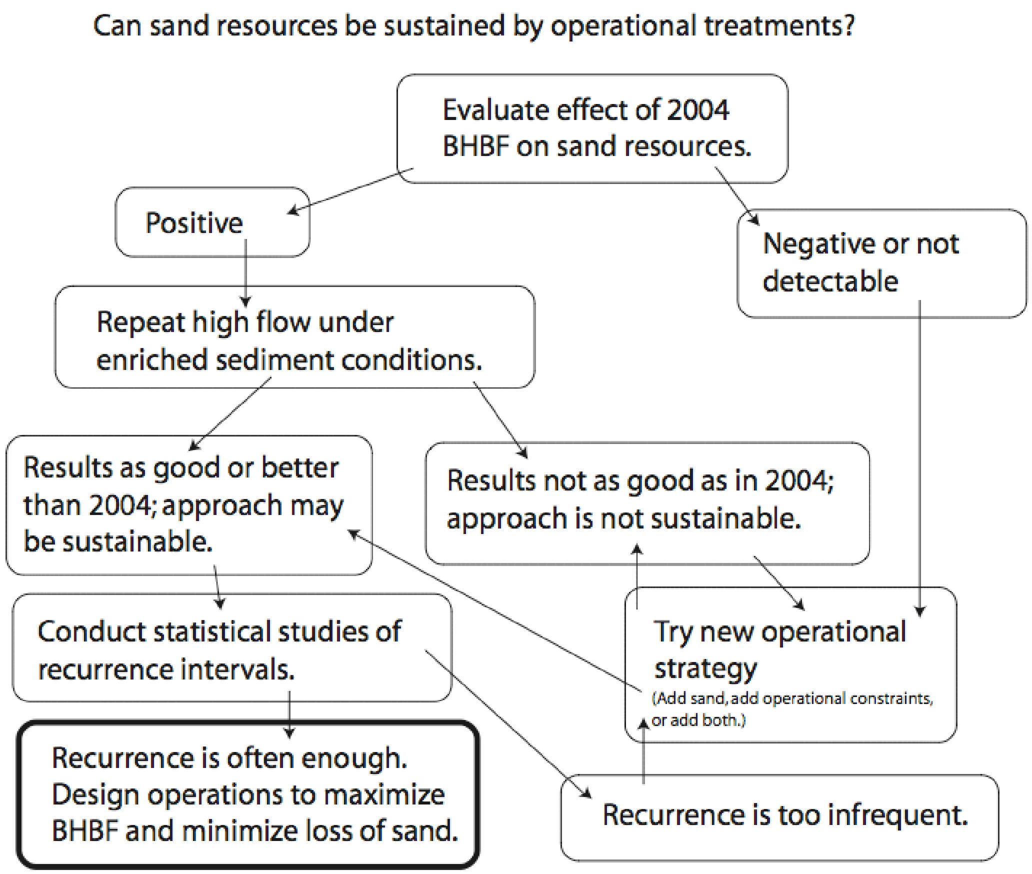


Figure 1. Flow chart for experiments testing the ability of operational treatments to restore sand resources.

Recent sand inputs to the Colorado River ecosystem from tributaries below Glen Canyon Dam provide an ideal opportunity to replicate the 2004 experimental flood—a key step in the flow chart—and address this strategic science question.

Sediment scientists at the U.S. Geological Survey recently produced the following estimates made on the basis of a combination of modeling and measurements over the last two years, with the following updated information included through October 18, 2006:

Sand Supply in the Main Channel of the Colorado River

Since July 1, 2006, the Paria has supplied between 1.32 and 1.98 million metric tons of sand, and the LCR has supplied between 260,000 and 380,000 metric tons of sand. The lesser tributaries in upper Marble Canyon are estimated to have supplied at least 170,000 metric tons of sand during this same period and perhaps much more.

Considering the uncertainties associated with the sand mass balance methods, the lower bound of the amount sand that accumulated in Marble Canyon since the 2004 experimental flood is 1.39 million metric tons, and the lower bound of sand that accumulated in upper Grand Canyon (below the Little Colorado River) is 300,000 metric tons. Following the scheme proposed by Science Planning Group and weighting the upper Grand Canyon sand at 50% (150,000 metric tons) and adding this reduced amount to the Marble Canyon sand gives a lower bound of 1.54 million metric tons. This exceeds the trigger by at least 540,000 metric tons.

Compared to sand status leading to the November 2004 flood, we now have almost 2 times that amount in upper Marble Canyon and about 3 times that amount in upper Grand Canyon. The recent Paria flood is the largest since 1998, and it is relatively rare to get large inputs from both the Paria River and LCR during the same year. Given the recent history of inputs from the Paria, Little Colorado, and lesser tributaries, the current opportunity to conduct an experimental flood with the amount of sediment now in the system should be considered rare, even if no additional sand is supplied. This large amount of sand recently supplied from the Paria, LCR, and lesser tributaries occurs only once in every 5-10 years. Furthermore, continued tributary flooding could result in additional new sand. This is perhaps the best opportunity managers will have in this decade to build on the results of 2004.

Upper Colorado River Basin Hydrology and Annual Glen Canyon Dam Releases

The same weather patterns that contributed to supply of sand to the Colorado River have apparently also supplied a significant volume of runoff to the Upper Colorado River Basin, and these inputs have come very early in the 2007 Water Year. It is anticipated that such early inflows to Lake Powell might result in Glen Canyon Dam releases later in the year (presumably, summer months with high daily peak discharges) exceeding the minimum release volume of 8.23 million acre feet. The known influence of any significantly increased monthly volume releases from the dam will be faster export (loss) of these new sand inputs. Sand-transport data collected during late-1999 and early-2000 indicate that if higher than 8.23 million acre-foot dam releases occur prior to conducting the next experimental flood, the recent large sand inputs will be exported from the canyon within 2007, and additional erosion of older sand in storage is likely. Such an increase in annual releases from the dam constrains the time available for exploiting the recent sand inputs.

Sediment Scientists' Recommendation for Restoration Experiment

Timing
Sand supplied by tributaries to the mainstem Colorado River is exported downstream relatively quickly, which constrains the time available for the new sand to be utilized for restoration (Rubin and others, 2002). The rate at which new sand is exported depends on water discharge and the availability of the new sediment (which in turn depends on the quantity and distribution of new sediment). The majority of sand in a moderate input is predicted to be lost within days (at discharges of >35,000 cfs) weeks (at discharges of ~25,000 cfs) or months (at discharges of ~15,000 cfs); at discharges of 10,000 cfs and lower, sand is retained for periods of months to years. As discussed previously (Rubin and others, 2002), the new sand will only be available for restoration if a flood is implemented promptly or if releases are constrained; as noted above, basin hydrology may prohibit low releases.

The goal of an experimental flood is three-fold: (1) to transfer inputs of tributary-supplied sand from the channel of the Colorado River to where it is needed (on the parts of the bars that will be emergent at typical dam releases) and where it will persist for longer timescales than on the channel bed, (2) to temporarily (over timescales of months) reduce the subsequent transport/export of sand by coarsening the sand on the surface of the channel bed and lower parts of bars, and (3) to maintain the increased bar size and sand resources until a subsequent experimental flood can be released from the dam. Preliminary analysis of data following the 2004 flood suggest that goals (1) and (2) were met, and that (3) can still be met if the next experimental flood is implemented in a timely manner.

Experimental plan
1) Use a combination of suspended-sediment measurements and the USGS's sand-routing model (Wiele and others, in press) to observe and predict downstream redistribution of new sand as a means of identifying optimal timing of an experimental flood (presumably in winter or spring 2007).

2) Repeat 2004 experimental flood hydrograph (in a month to be determined by 1 above, and by managers), thereby using the flood experiment as a monitoring tool. Differences in bar size between successive experiments will provide information about success or failure of a sediment-management program based purely on dam operations (see above diagram).

3) Use experience gained from the 1996 and 2004 science programs to design a smaller, lower-cost, surveying and change detection program. For example, instead of conducting both pre- and post-flood surveys, researchers could survey bars only after the flood.

In addition to addressing the strategic science question identified in the flow chart, this experimental plan has the potential to increase the ecosystem's sand resources. There is no guarantee that flow-only restoration is possible, but we know of no better flow-only option than an experiment to retain these large recent inputs.

Reporting of Future Inputs and Exports

Tributaries are continuing to supply additional sand to the Colorado River. We will provide undated reports of the mass balance by email. In the meantime, please feel free to contact me with any additional questions that you or the stakeholder group might have regarding this updated information on the sand mass balance and associated scientific recommendations. I can be reached at (831) 427-4736.

References

Hazel, J., Jr., Topping, D.J., Schmidt, J.C., and Kaplinski, M., 2006, Influence of a dam on fine-sediment storage in a canyon river: Journal of Geophysical Research, v. 111, F01025, 16 p.

Randall, T.J., Lyons, J.K., Christensen, R.J., and Stephen, R.D., Grand Canyon Sediment Augmentation Appraisal Engineering Report: Bureau of Reclamation, draft report, Oct 1, 2006.

Rubin, D.M. and Topping, D.J., 2001, Quantifying the relative importance of flow regulation and grain-size regulation of suspended-sediment transport (a) and tracking changes in grain size on the bed (b): Water Resources Research, v. 37, p, 133-146.

Rubin, D.M., Topping, D.J., Schmidt, J.C., Hazel, J., Kaplinski, M., and Melis, T.S., 2002, Recent sediment studies refute Glen Canyon Dam hypothesis: Eos, June, 2002, p. 273, 277-278.

Schmidt, J. C., Topping, D. J., Grams, P. E., and Hazel, J. E., 2004, System-wide changes in the distribution of fine sediment in the Colorado River corridor between Glen Canyon Dam and Bright Angel Creek, Arizona: Final report submitted to the Grand Canyon Monitoring and Research Center, 107 p.

Topping, D.J., Rubin, D.M., and Vierra, L.E., Jr., 2000, Colorado River sediment transport: Part 1: Natural sediment supply limitation and the influence of Glen Canyon Dam: Water Resources Research, v. 36, p. 515-542.

Topping, D.J., Rubin, D.M., Schmidt, J.C., Hazel, J.E., Jr., Melis, T.S., Wright, S.A., Kaplinski, M., Draut, A.E., and Breedlove, M.J., 2006, Comparison of sediment-transport and bar-response results from the 1996 and 2004 controlled-flood experiments on the Colorado River in Grand Canyon: CD-ROM Proceedings of the 8th Federal Inter-Agency Sedimentation Conference, Reno, Nevada, April 2-6, 2006, ISBN 0-9779007-1-1.

Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., 1999, The Controlled Flood in Grand Canyon: Geophys. Monogr. Ser., vol. 110, AGU, Washington, D.C.

Wiele, S.M., P.R. Wilcock, P.E. Grams, in press, Reach-averaged sediment routing model of a canyon river: Water Resources Research.

Wright, S.A., Melis, T.S., Topping, D.J., and Rubin, D.M., 2005, Summary of the effects of Glen Canyon Dam operations on downstream sand transport and sandbars along the Colorado River in Grand Canyon, *in* Gloss, S.P., Lovich, J.E., and Melis, T.S., eds., The State of the Colorado River Ecosystem in Grand Canyon: U.S. Geological Survey Circular 1282.

GCMRC's EXPERIMENTAL RESEARCH UPDATE "SEDIMENT"

Part I - Update on 2004 Sediment Test Findings
&
Part II - 2006 Status Of Sand Supplies In The Colorado Below Glen Canyon Dam

Presented to the Glen Canyon Dam Adaptive Management Workgroup

08:30 – 09:15

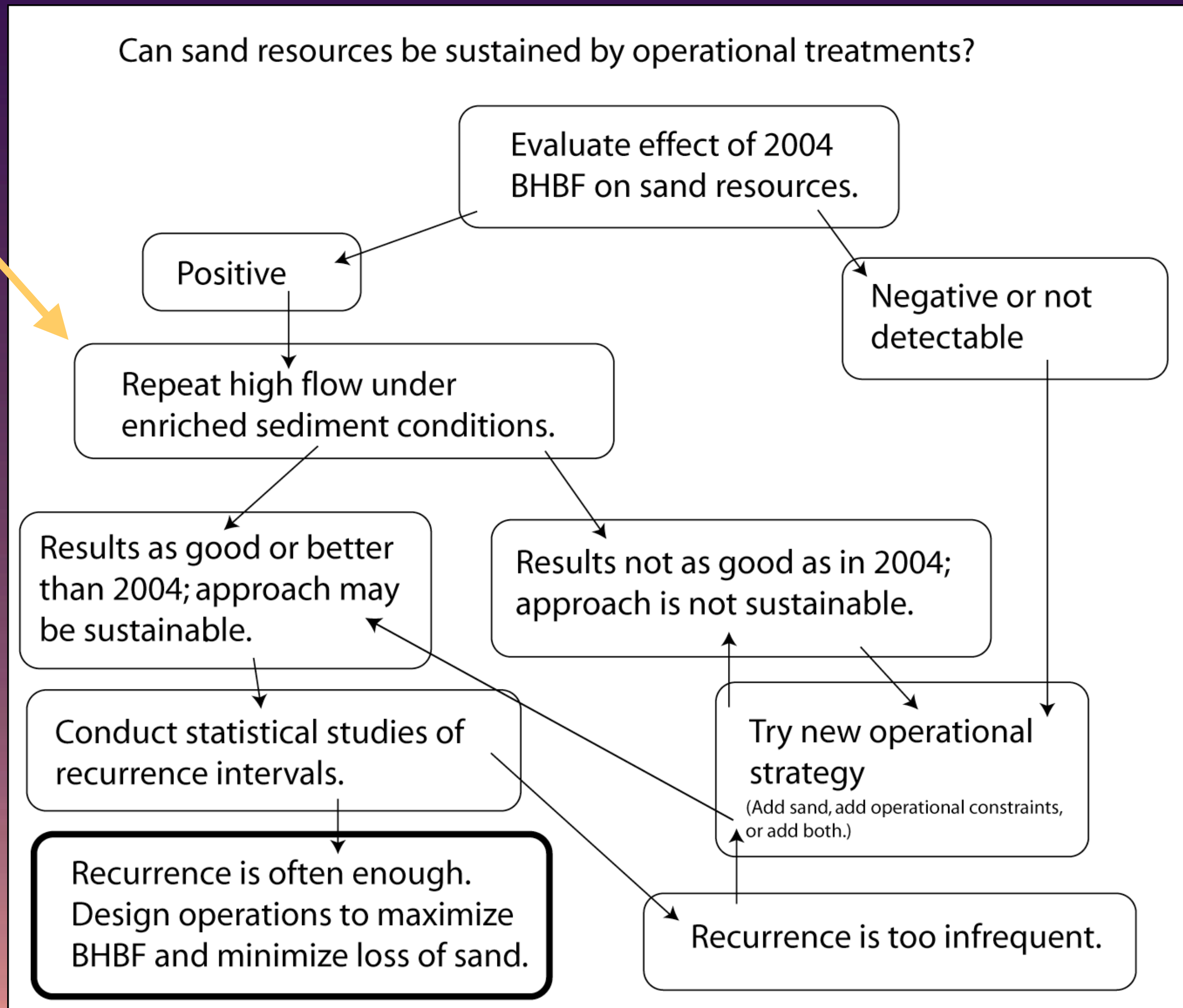
December 6, 2006

USGS
science for a changing world

Can Colorado River Sand Bars be Restored/Maintained by Downstream Sand Inputs + Managed GCD Flows?

Taking a Strategic, Science Based Approach to the Question of BHBFs

Scientists Currently Recommend



PART I - Explaining the 2004 Test Results (Topping and others, 2006)

- Mixed Sand Bar Results - There was less sand system-wide in 2004 than in 1996, owing to sand export and sand bar erosion for 8 years under MLFF

- Robust Response in Upper Marble Canyon - Owing to new localized sand enrichment by Paria River, bars in Upper Marble Canyon increased in area and volume - results were mixed downstream where supply was depleted

- Mass Balance - The net mass balance for sand during the 2004 test was actually positive system-wide, despite depleted conditions below Marble Canyon (an encouraging sign tied to a shorter peak-flow duration)

- More Sand Needed – continued sand bar restoration likely requires additional high flows timed in combination with new sand from tributaries – more uniform distribution of new sand might result in more uniform response

1996

Channel was sand-depleted.

Bar growth was minimal or negative.

Not a sustainable plan.

1996

Channel was sand-depleted.

Overall sandbar growth was minimal or negative.

Not a sustainable plan.

pre-1996 flood

post-1996 flood

1996

Channel was depleted.

Overall sandbar growth was minimal or negative.

Not a sustainable plan.

2004

- Channel was moderately enriched.
- Bar growth was more substantial within enriched reach.
- Promising, but additional sand is needed. (Requires more frequent floods, exploiting bigger inputs, adding sediment, or constraining flows between floods.)

1996

Channel was depleted.
Overall sandbar growth was minimal or negative.
Not a sustainable plan.

2004

- Channel was moderately enriched.
- Bar growth was more substantial within enriched reach.
- Promising, but more sand is needed. (Requires more frequent floods, exploiting bigger inputs, adding sediment, or constraining flows between floods.)

pre-2004 flood

post-2004 flood

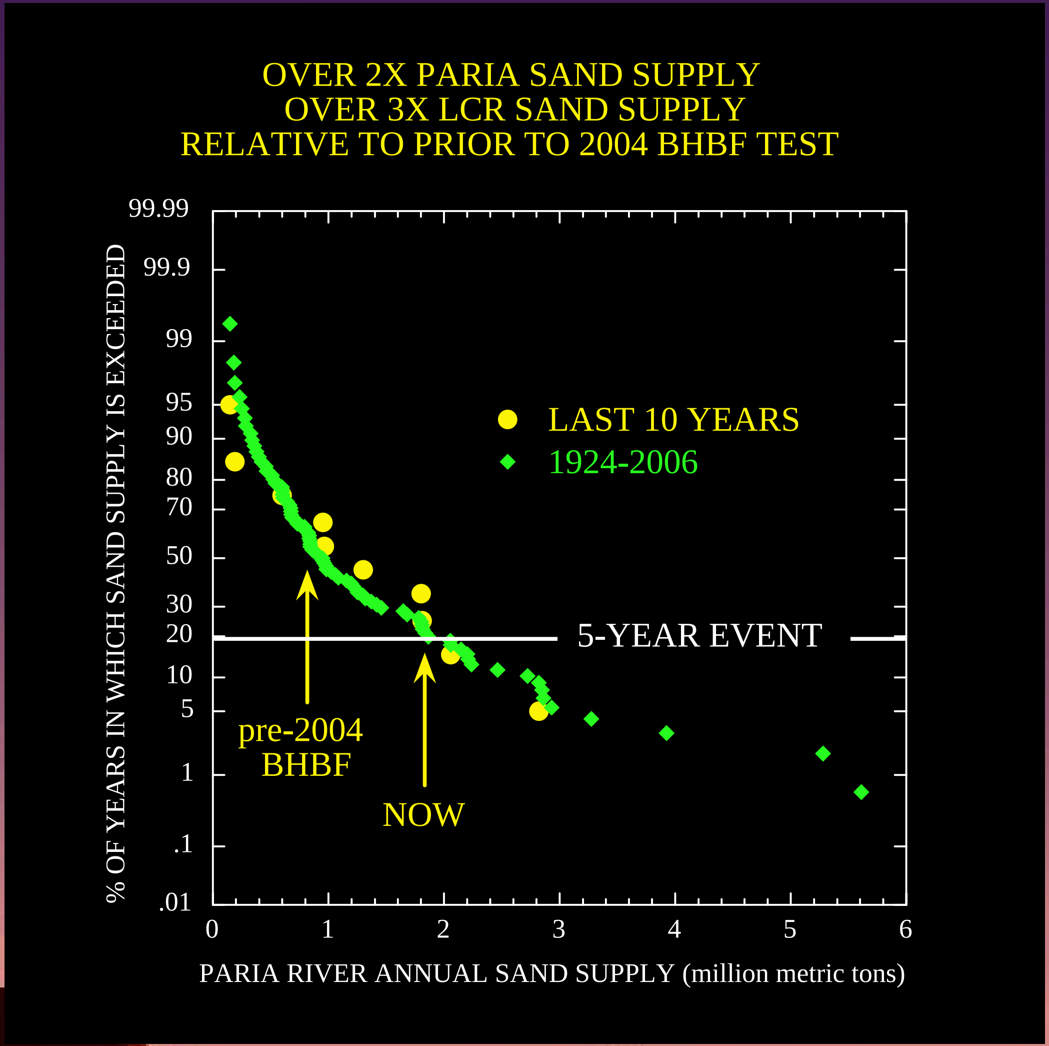
PART II

Where are We On Sand Supply in 2006 ?

- Channel is a factor of 2 to 3 times more sand-enriched than in 2004.
- Potential to increase bar size and suppress subsequent sand export, while testing flow-only treatment.

STATUS OF SAND SUPPLIES IN THE COLORADO BELOW GLEN CANYON DAM

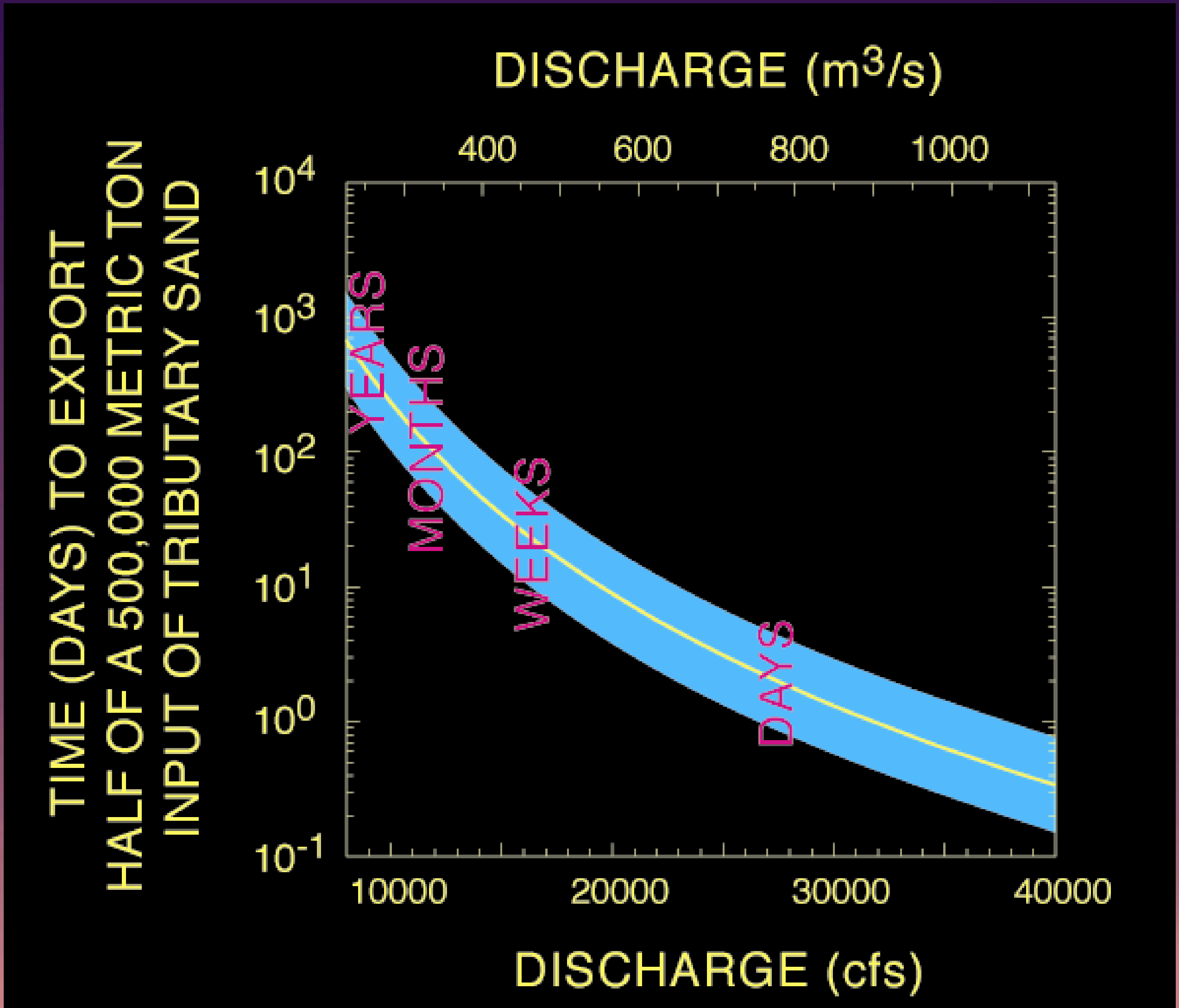
Tributary Have Delivered 1.7 – 2.6 Million Metric Tons of SAND



Experimental Research Opportunities to study beach habitat building flows

The Paria River Inputs are Now Equal to Five-Year Recurrence Interval

Limited Time To Exploit New Sand Inputs



Rubin et al., 2002, *Eos*.

Potential for Equalization Releases in WY 2007

- October Inflow Has Increased Probability That WY 2007 Annual Release May Include Equalization Flows From Glen Canyon Dam

- New Sand Supplies Will Be Exported Faster Under Higher Peak Flows Associated With Larger Summer Volumes

- Probability of Equalization Releases in WY 2007 is currently 50 %

- 50 % Exceedance [A-J ~ 91 %]	Avg Summer Releases ~ 13,000 cfs
- 40 % Exceedance [A-J ~ 101%]	Avg Summer Releases ~ 16,000 cfs
- 30 % Exceedance [A-J ~ 114 %]	Avg Summer Releases ~ 20,000 cfs
- 20 % Exceedance [A-J ~ 131 %]	Avg Summer Releases ~ 22,000 cfs
- 10 % Exceedance [A-J ~ 155 %]	Avg Summer Releases ~ 24,000 cfs*

* may not be achievable due to maintenance

RECLAMATION
Managing Water in the West

USGS