BRIEFING MEMORANDUM

Date: **January 20, 2011**
To: **GCDAMP - Technical Workgroup**
From: **John Hamill, Chief and Ted Melis, Deputy Chief, both at USGS Grand Canyon Monitoring and Research Center; (o) 928-556-7364 or (c) 928-607-5253**

SUBJECT: **Summary of upcoming U.S. Geological Survey Circular 1366 on the results of three high-flow experiments released from Glen Canyon Dam, Arizona**

BACKGROUND

Three high-flow experiments (HFEs) were conducted by the U.S. Department of the Interior at Glen Canyon Dam, Arizona, in March 1996, November 2004, and March 2008. These experiments, also known as artificial or controlled floods, were scheduled releases of water from Glen Canyon Dam above powerplant capacity that were designed to mimic some aspects of pre-dam Colorado River seasonal flooding. The goal of these experiments was to determine whether high flows could be used to benefit important physical and biological resources in Glen Canyon National Recreation Area and Grand Canyon National Park that are being adversely affected by the operation of the dam. Examples of these downstream resources include native species, such as the endangered humpback chub (*Gila cypha*), sandbar habitats, cultural sites, and recreational resources. The report summarizes and synthesizes the extensive body of results published since 1996 and outlines a possible strategy for initiating future HFEs.

FINDINGS

Sediment and Sandbars

Five key sediment conclusions have important implications for designing future HFEs:

1. HFEs effectively build sandbars by transferring sand from the riverbed to sandbars either by eroding existing low-elevation sandbars or by using tributary-supplied sand.
2. HFEs conducted soon after tributary flooding accompanied by sand enrichment are effective at increasing sandbar area and volume and less likely to result in the erosion of low-elevation parts of sandbars.
3. Sandbars are rebuilt relative quickly (hours to a few days) under sand-enriched conditions but then also tend to erode quickly over days to months following an HFE.
4. Monitoring data show that sandbars erode more quickly as release volumes and daily fluctuations increase; the rate of erosion is reduced when tributary sand production occurs following sandbar building.
5. From February 1996 and October 2008 many of the sandbars at long term study sites in Grand Canyon experienced slight increases in size (both area and volume) over that period despite ongoing erosion of the deposits. This increase occurred during a period of variable basin hydrology which included 6 years of above annual minimum releases and 7 years of minimum annual releases.

Biological Resources

Four biological conclusions have important implications for designing future HFEs:

1. On the basis of 2008 HFE research, spring-timed HFEs have the potential to significantly increase the size of the rainbow trout population in the Lees Ferry reach and downstream areas being managed for native fish.
2. Increases in the rainbow trout population associated with the March 2008 HFE appear to have been the result of improvements in spawning/rearing habitat and increased availability of better quality food that improved the survival of juvenile trout.
3. The large increases of rainbow trout numbers documented in the river reach near the Little Colorado River confluence may adversely affect the endangered humpback chub, because rainbow trout are known predators of young chub and compete with native fish for limited food and habitat.
4. HFEs resulted in no measurable direct impact, positive or negative, to humpback chub populations, possibly because of the short duration of the HFE (2-1/2 to 7 days).

A SCIENCE-BASED STRATEGY FOR FUTURE HIGH-FLOW EXPERIMENTATION

Key Questions

1. Can sandbar building during HFEs exceed sandbar erosion during periods between HFEs, such that sandbar size can be increased and maintained over several years?
2. Does the seasonal timing of HFEs influence the rainbow trout response**?**

Strategy

- An adaptive management approach would be most effective for assessing the key questions above. The diverse objectives of river managers means that potential impacts to other downstream resources must also be carefully considered.

- With only 6-10 percent of the pre-dam sand supply still entering Grand Canyon National Park from the Paria and Little Colorado Rivers, rebuilding and maintaining sandbars systemwide requires repeated HFEs following typical tributary floods that occur annually. This is true for two reasons: (1) typical dam operations do not allow multiyear accumulation of tributary sand inputs to occur in the river channel, and (2) new sandbars are eroded to some extent by typical dam releases following each HFE.

- Paria River flooding is the primary source of new sediment inputs; flooding primarily occurs from mid-summer through early fall; therefore, ideally, HFEs would be timed for mid-October or November. Because the Paria River more rarely experiences winter flooding, resulting in an HFE in mid-March to April under this strategy, about two-thirds of future HFEs would occur during the fall. The Little Colorado River also delivers important new sand supplies, and those inputs can also be considered by managers annually as criteria for the next HFE are evaluated relative to the river's sand accounting (see attached figure).

- If future flow experiments are strategically timed to follow a variety of tributary floods and HFE hydrographs are appropriately designed (peak magnitudes and durations) to match the volume of new sand annually delivered to the river, scientists hypothesize that it may be possible to enlarge and maintain sandbars through time.

Addressing Uncertainty

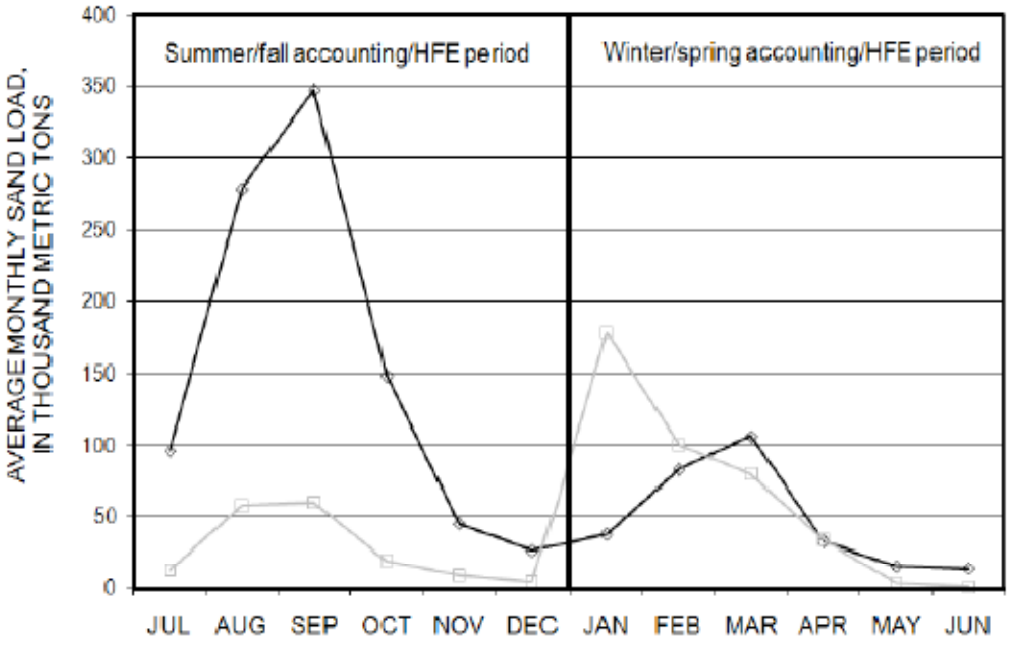
Although the strategy suggested above is made on the basis of monitoring data and published results, uncertainties exist about its ability to maximize future sandbar building and how HFEs will affect other resources over the long term. **It is thus critical that long-term monitoring of the effects of HFEs be conducted and the results evaluated to adapt this strategy to changing conditions.**

- If monitoring under the suggested triggering strategy indicates that sandbars continue to erode or cannot be rebuilt and sustained at a desired level, then managers may choose other experimental options, such as further constraining dam releases, augmenting sand supply to Grand Canyon from sources in Lake Powell, or both.

- Tracking the status and response of the aquatic food web and fish populations to HFEs is critical.

Although the proposed strategy does not guarantee success, sandbar trends without HFEs are one of the few outcomes that sediment researchers can predict with absolute certainty: without HFEs, sandbar size will decrease through time.

FIGURE CAPTION - Historical USGS data on Paria and Little Colorado River flow and sand delivery to the Colorado River (as measured and modeled tributary stations below the dam) supports the proposed fall and spring strategy for releasing future high-flow experiments (HFEs) from Glen Canyon Dam that are intended to maximize rebuilding and maintenance of sandbars. Diamonds = Paria River and Squares = Little Colorado River data.



Completed and In-Review 2008 High-Flow Experiment Scientific Reports

(All available at http://www.gcmrc.gov, excepting four currently still pending final USGS approval)

The 24 reports listed below (20 final and 4 still considered to be "*in review*" under USGS Fundamental Science Practices) are referenced to the individual research project numbers (Projects 1–7 and associated post-HFE monitoring data) and activities described in the December 2007 *Science Plan for a March 2008 High-Flow Experiment*, as recommended by AMWG in January 2008 and approved by the U.S. Department of the Interior for implementation in February 2008. An upcoming USGS circular intended to summarize and synthesize all HFE results for three flow experiments with peak flows exceeding GCD powerplant capacity (those released in 1996, 2004, and 2008) is anticipated by early 2011 in fulfillment of Project 7 (Synthesis of knowledge).

PROJECT 1—SEDIMENT, ARCHAEOLOGICAL SITES, AND BACKWATERS

Project 1.A—Sand budgeting

Topping, D.J., Rubin, D.M., Grams, P.E., Griffiths, R.E., Sabol, T.A., Voichick, N., Tusso, R.B., Vanaman, K.M., and McDonald, R.R., 2010, Sediment transport during three controlled-flood experiments on the Colorado River downstream from Glen Canyon Dam, with implications for eddy-sandbar deposition in Grand Canyon National Park: U.S. Geological Survey Open-File Report 2010-1128, 111 p., at http://pubs.usgs.gov/of/2010/1128/.

Project 1.B—Eddy sandbar studies

Wright, S.A., and Kaplinski, M., *in press*, Flow structures and sandbar dynamics in pool-rapid units during a controlled flood, Colorado River, Arizona: *Journal of Geophysical Research-Earth Surface*.

Logan, B., Nelson, J., McDonald, R., and Wright, S., 2010, Mechanics and modeling of flow sediment transport and morphologic change in riverine lateral separation zones, *in* Hydrology and sedimentation for a changing future; existing and emerging issues (Joint Federal Interagency Conference 2010—Federal Interagency Hydrologic Modeling, 4th, and Federal Interagency Sedimentation, 9th), Las Vegas, Nev., June 27- July 1, Proceedings: v. ISBN: 978-0-9779007-3-2, CD-ROM.

Project 1.C—Response of sandbars and select cultural sites

Hazel, J.E., Jr., Grams, P.E., Schmidt, J.C., and Kaplinski, M., 2010, Sandbar response in Marble and Grand Canyons, Arizona, following the 2008 high-flow experiment on the Colorado River: U.S. Geological Survey Scientific Investigations Report 2010-5015, 52 p., at http://pubs.usgs.gov/sir/2010/5015/.

Rubin, D.M., Topping, D.J., Chezar, H., Hazel, J.E., Schmidt, J.C., Breedlove, M., Melis, T.S., and Grams, P.E., 2010, 20,000 grain-size observations from the bed of the Colorado River and implications for sediment transport through Grand Canyon, *in* Hydrology and sedimentation for a changing future; existing and emerging issues (Joint Federal Interagency Conference 2010—Federal Interagency Hydrologic Modeling, 4th, and Federal Interagency Sedimentation, 9th), Las Vegas, Nev., June 27- July 1, Proceedings: v. ISBN: 978-0-9779007-3-2, CD-ROM.

Draut, A.E., Topping, D.J., Rubin, D.M., Wright, S.A., and Schmidt, J.C., 2010b, Grain-size evolution in suspended sediment and deposits from the 2004 and 2008 controlled-flood experiments in the Marble and Grand Canyons, Arizona, *in* Hydrology and sedimentation for a changing future; existing and emerging issues (Joint Federal Interagency Conference 2010—Federal Interagency Hydrologic Modeling, 4th, and Federal Interagency Sedimentation, 9th), Las Vegas, Nev., June 27- July 1, Proceedings: v. ISBN: 978-0-9779007-3-2, CD-ROM.

Draut, A.E., Sondossi, H.A., Hazel, J.E., Jr., Andrews, T., Fairley, H.C., Brown, C.R., and Vanaman, K.M., 2009, 2008 Weather and aeolian sand-transport data from the Colorado River corridor, Grand Canyon, Arizona: U.S. Geological Survey Open-File Report 2009-1190, 98 p., at http://pubs.usgs.gov/of/2009/1190/of2009-1190.pdf.

Draut, A.E., Hazel, J.E., Jr., Fairley, H.C., and Brown, C.R., 2010a, Aeolian reworking of sandbars from the March 2008 Glen Canyon Dam high-flow experiment in Grand Canyon, *in* Melis, T.S., Hamill, J.F., Bennett, G.E., Coggins, L.G., Jr., Grams, P.E., Kennedy, T.A., Kubly, D.M., and Ralston, B.E., eds., Proceedings of the Colorado River Basin Science and Resource Management Symposium, November 18-20, 2008, Scottsdale, Arizona: U.S. Geological Survey Scientific Investigations Report 2010-5135, 325-331 p., at http://pubs.usgs.gov/sir/2010/5135/.

Project 1.D—Biological and physical aspects of backwater habitats

Grams, P.E., Hazel, J.E., Schmidt, J.C., Kaplinski, M., Wright, S.A., Topping, D.J., and Melis, T.S., 2010a, Geomorphic response of sandbars to the March 2008 high-flow experiment on the Colorado River downstream from Glen Canyon Dam, *in* Hydrology and sedimentation for a changing future; existing and emerging issues (Joint Federal Interagency Conference 2010--Federal Interagency Hydrologic Modeling, 4th, and Federal Interagency Sedimentation, 9th), Las Vegas, Nev., June 27- July 1, Proceedings: v. ISBN: 978-0-9779007-3-2, CD-ROM.

Grams, P.E., Schmidt, J.C., and Andersen, M.E., 2010b, 2008 high-flow experiment at Glen Canyon Dam—morphologic response of eddy-deposited sandbars and associated aquatic backwater habitats along the Colorado River in Grand Canyon National Park: U.S. Geological Survey Open-File Report 2010-1032, 73 p., at http://pubs.usgs.gov/of/2010/1032/.

Behn, K.E., Kennedy, T.A., and Hall, R.O., Jr., 2010, Basal resources in backwaters of the Colorado River below Glen Canyon Dam—effects of discharge regimes and comparison with mainstem depositional environments: U.S. Geological Survey Open-File Report 2010-1075, 25 p., at http://pubs.usgs.gov/of/2010/1075/of2010-1075.pdf. (This report is not directly tied to HFE reporting, however, the report's findings relate to Projects 1.D and 3.)

PROJECT 2—RIPARIAN VEGETATION

Ralston, B.E., 2010, Riparian vegetation response to the March 2008 short-duration, high-flow experiment—implications of timing and frequency of flood disturbance on nonnative plant establishment along the Colorado River below Glen Canyon Dam: U.S. Geological Survey Open-File Report 2010-1022, 30 p., at http://pubs.usgs.gov/of/2010/1022/.

PROJECT 3—AQUATIC FOOD BASE

Rosi-Marshall, E.J., Kennedy, T.A., Kincaid, D.W., Cross, W.F., Kelly, H.A.W., Behn, K.A., White, T., Hall, R.O., Jr., and Baxter, C.V., 2010, Short-term effects of the 2008 high-flow experiment on macroinvertebrates in the Colorado River below Glen Canyon Dam, Arizona: U.S. Geological Survey Open-File Report 2010-1031, 28 p., at http://pubs.usgs.gov/of/2010/1031/.

PROJECT 4—RAINBOW TROUT

Project 4.A—Redds study

Korman, J., Kaplinski, M., and Melis, T.S., 2010, Effects of high-flow experiments from Glen Canyon Dam on abundance, growth, and survival rates of early life stages of rainbow trout in the Lees Ferry reach of the Colorado River: U.S. Geological Survey Open-File Report 2010-1034, 31 p. http://pubs.usgs.gov/of/2010/1034/.

Korman, J., Kaplinski, M. and T.S. Melis. *In press*, Effects of fluctuation flows and a controlled flood on incubation success and early survival rates and growth of age-0 rainbow trout in a large regulated river, *Transactions of the American Fisheries Society*.

Korman, J. and Melis, T.S., 2011, The Effects of Glen Canyon Dam Operations on Early Life Stages of Rainbow Trout in the Colorado River, U.S. Geological Survey Fact Sheet, FS-2011-3002, 4 p.

Project 4.B—Movement study

Hilwig, K.D., and Makinster, A.S., 2010, Evaluating effects of a high-flow event on rainbow trout movement in Glen and Marble Canyons, Arizona, by using acoustic telemetry and relative abundance measures, *in* Melis, T.S., Hamill, J.F., Bennett, G.E., Coggins, L.G., Jr., Grams, P.E., Kennedy, T.A., Kubly, D.M., and Ralston, B.E., eds., Proceedings of the Colorado River Basin Science and Resource Management Symposium, November 18-20, 2008, Scottsdale, Arizona: U.S. Geological Survey Scientific Investigations Report 2010-5135, 219-225 p., at http://pubs.usgs.gov/sir/2010/5135/.

Makinster, A.S., Persons, W.R., Avery, L.A. and Bunch, A.J., 2010, Colorado River fish monitoring in Grand Canyon, Arizona—2000 to 2009 summary: U.S. Geological Survey Open-File Report 2010–1246, 26 p.

PROJECT 5—LAKE POWELL QUALITY OF WATER

Vernieu, W.S., Effects of the 2008 high-flow experiment on water quality in Lake Powell and Glen Canyon Dam releases, Utah-Arizona: U.S. Geological Survey Open-File Report 2010–1159.

PROJECT 6—KANAB AMBERSNAIL CONSERVATION MEASURES

Sorensen, J.A., Kanab Ambersnail habitat mitigation for the 2008 high flow experiment—August 2009 draft cooperator report from Arizona Game and Fish Department: Phoenix, Arizona Game and Fish Department.

PROJECT 7—SYNTHESIS OF KNOWLEDGE

Melis, T.S., Topping, D.J., Grams, P.E., Rubin, D.M., Wright, S.A., Draut, A.E., Hazel, J.E., Jr., Ralston, B.E., Kennedy, T.A., Rosi-Marshall, E., Korman, J., Hilwig, K.D., and Schmit, L.M., 2010, 2008 High-flow experiment at Glen Canyon Dam benefits Colorado River resources in Grand Canyon National Park: U.S. Geological Survey Fact Sheet 2010-3009, 4 p., at http://pubs.usgs.gov/fs/2010/3009/.

Pending 2008 High-Flow Experiment Reports and Related Reports

Anticipated to be USGS Approved before February 1, 2011

Cross, W.F., Baxter, C.V., Donner, K.C., Rosi-Marshall, E.J., Kennedy, T.A., Hall, Jr., R.O., Wellard-Kelly, H.A. and Rogers, R.S., *in review*, Ecosystem ecology meets adaptive management: food web response to a controlled flood on the Colorado River, Glen Canyon, *Ecological Applications*.

Grand Canyon Monitoring and Research Center (five chapters with multiple authors), *in review*, The effects of three Glen Canyon Dam high-flow experiments on the Grand Canyon ecosystem: U.S. Geological Survey Circular.

Makinster, A.S., L.A. Avery, and W.R. Persons. *in review*. Status of the Lees ferry rainbow trout fishery: U.S. Geological Survey Open File Report 2010-xxxx.

Melis, T.S., Korman, J. and Kennedy, T.A. *in review*, Abiotic & Biotic Responses of the Colorado River to the March 2008 and Two Earlier Controlled Flood Experiments at Glen Canyon Dam, Arizona, USA, *River Research and Applications*.