PROJECT A.2 ONGOING PROVISIONAL MONITORING – DOWNSTREAM QUALITY-OF-WATER FOR PHYSICAL, BIOLOGICAL AND CHEMICAL SAMPLING (INCLUDES R&D (MODELING))

FISCAL YEAR 2006 PROJECT REPORT FOR THE GLEN CANYON DAM ADAPTIVE MANAGEMENT PROGRAM	SUBMISSION DATE:	*02/20/2007
(1.) SUBMITTING AGENCY:	USGS – SBSC – Grand Canyon Monitoring & Research Center	
(2.) GCDAMP/GCMRC AWP ID/OTHER NO.:	Glen Canyon Dam Adaptive Management Program, Fiscal Year 2006 Budget & Work Plan, A.2 (GCMRC No. BNE2A)	
(3.) PROJECT TITLE:	Ongoing Provisional Monitoring – Downstream Quality-of-Water for Physical, Biological and Chemical Sampling (includes R&D (modeling))	

(4.) PRINCIPAL INVESTIGATOR INFORMATION:

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(5.) STATEMENT OF PROBLEM:

Glen Canyon Dam has altered the character of the water that is released downstream into the Colorado River. The supply of fine sediment has been reduced to nearly zero, which has impacted fine sediment deposits and turbidity in Glen, Marble, and Grand Canyons. The thermal regime of the releases has changed from seasonal variations that followed air temperatures to nearly constant release temperatures throughout the year, which are colder in the summer and warmer in the winter than pre-dam temperatures. These changes, as well as changes in the downstream delivery of minerals, nutrients, and carbon have altered the ecosystem of the Colorado River downstream from Glen Canyon Dam. The Lake Powell Project characterizes the water quality of the lake and downstream releases. This project monitors how the releases affect the downstream ecosystem and develops tools to assist decision-makers in the management of Glen Canyon Dam.

The primary linkage between dam operations and the response of the physical, biological, and cultural resources in the Colorado River ecosystem between Glen Canyon Dam and Lake Mead is through the discharge and quality of water in the Colorado River. At the 2004 AMWG priority-setting workshop, questions relating specifically to water discharge and quality were three of the top five priorities of the AMP, and water discharge and quality issues influence the outcomes of every AMP goal. Releases from Glen Canyon Dam provide the principal control on the discharge of water in the Colorado River between Glen Canyon Dam and Lake Mead. This reach is hereafter referred to as the Colorado River ecosystem (CRE). Only during periods of large tributary floods do tributaries exert any substantial control on the discharge of the Colorado River in the CRE. Quality of water, using standard definitions, consists of temperature and the dissolved and suspended (inorganic and organic) material in the water column.

	Water temperature, dissolved salts, dissolved oxygen, suspended-sediment concentration and grain size, and suspended organic material therefore all contribute to water quality. Water quality in the CRE is driven in decreasing order of importance by dam operations, tributary activity, and mainstem biological activity (e.g., algal effects on turbidity).
(6.) OBJECTIVES:	The downstream IQWP characterizes the water discharge and water quality of the Colorado River and key tributaries between Glen Canyon Dam and the upper reaches of Lake Mead (River Miles –15 to 274). This project has two major components. The first component is focused on monitoring and modeling the mass-balance of fine sediment in the CRE. The second component of the downstream IQWP is focused on characterizing other water quality components of the ecosystem, such as water temperature, oxygen, nutrients, and carbon. Each component has monitoring and research elements as described below. **Downstream Monitoring Components:** 1. **Fine sediment mass balance**: Use of laser-acoustic system and conventional suspended-sediment samples to monitor transport at several locations along the mainstem Colorado River and on key tributaries. Monitoring data are used to provide a continuous accounting of the mass-balance (input minus export) of sand and fine sediment in Marble and Grand Canyons and to assess the impacts of experimental flows on the mass-balance. 2. **Continuous water quality monitoring:** Temperature, conductivity, dissolved oxygen, and pH are monitored at several locations along the mainstem Colorado River and key tributaries. Most sites are coincident with the mass-balance monitoring locations. Temperature monitoring in selected backwater habitat areas. Data are used to characterize the thermal regime and longitudinal gradient in mineral and oxygen content of the river, and to calibrate and validate numerical models. **Research Components:** 1. **Numerical model development and application**: Fine sediment transport models are currently in use and under development. Research includes flume studies and detailed flow measurements of sediment transport dynamics. Water temperature model development is underway. Research includes detailed measurements of heat exchange between the river and the atmosphere; water temperature dynamics in backwater habitat areas. 2. **Real-time two-way telemetry**: A system is being developed to provide two-way telemetry between the office and instrumentation in the Canyon. The two-way communication not only provides real-time access to data,

	but also allows the user full control of the instrument from the office. The system is being developed in a generic fashion to allow use with any instrument that uses serial communications.
(7.) RELATIONSHIP TO MRP:	Project A.2 in the 2006 annual work plan
(8.) METHODOLOGY:	Surface water measurements (i.e. stage and discharge) are made using standard USGS methods (described in *Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 3, Section A*) at the following sites: Colorado River at Lees Ferry, Paria River at Lees Ferry, Little Colorado River near Cameron, Little Colorado River near mouth, Colorado River at Grand Canyon, and Colorado River near Diamond Creek. At all sites, 15-minute data is available in approximate real-time (every 4 hours) through the USGS NWIS database (http://waterdata.usgs.gov/az/nwis/rt). The surface water gages are maintained and operated by the USGS Water Resources Discipline Arizona Water Science Center. Discharge-release data from Glen Canyon Dam are also estimated by the Bureau of Reclamation (http://www.wapa.gov/crsp/operatns/gcSCADAdata.htm). In addition, stage and suspended-sediment concentration and grain size are monitored every 15 minutes using laser-acoustic technologies at the following sites: 30-mile, 61-mile, 87-mile, and 226-mile. Water temperature and conductivity in the mainstem and major tributaries are monitored using a combination of Onset Hobo Water Temp Pro Loggers and YSI 6920 Multi-Parameter Loggers. Water temperature is monitored at eight mainstem locations: below the dam, Lees Ferry, 30-mile, 61-mile, 87-mile, 166-mile, 226-mile, and 246-mile. The Lees Ferry, 87-mile, and 226-mile sites correspond to existing surface water gages. Water temperature is also monitored on selected tributaries. The mainstem water temperature data is currently being used to calibrate and test a one-dimensional temperature model. Specific conductance is monitored below the dam, at Lees Ferry, 30-mile, 61-mile, 87-mile, and 226-mile. Spikes in specific conductance allow the downstream fate of more-saline water introduced by tributaries during floods (and therefore potentially the organic and washload components of the flux introduced by these tributaries) to be tracked in the Colorado River. Dissolved oxygen and pH are monitored continuously below the dam and at Lees Ferry. Other water-quality parameters (including full water chemistry) are measured four times annually at the Colorado River at Lees Ferry gaging station by the Arizona Water Science Center as part of the AZDEQ program, and seven time annually at the Colorado River above Diamond Creek gaging station by the Arizona Water Science Center as part of the NASQWN program. The tributary supply of sediment to the Colorado River is computed using a combination of physically based models and

	measurements. On a near real time basis, the concentration and grain-size distribution of the sand and finer material supplied by the major tributaries (Paria and Little Colorado Rivers) are computed using a geomorphically coupled flow and sediment-transport model. Sediment-transport measurements are collected on these on two major tributaries by conventional and pump methodologies by the USGS WRD-Arizona Water Science Center and provided to our laboratory. As sediment-transport data become available from our laboratory, the predictions from this model are verified (to within the error in the measurements). Inputs of suspended sand (with grain size) and suspended silt and clay from the lesser tributaries are computed based on stage and sediment data collected in a network we established beginning in 2000. This network now covers 55% of the formerly ungaged tributary area between Glen Canyon Dam and the Little Colorado River. Sediment-transport data collected under the downstream IQW project are used to compute flux-based "mass-balance" sediment budgets for the following reaches of the CRE: river-miles –15 to 0 (Glen Canyon), river-miles 0 to 30 (upper Marble Canyon), river-miles 30 to 62 (lower Marble Canyon), river-miles 62 to 88 (upper or eastern Grand Canyon), river-miles 87 to 226 (lower or western Grand Canyon).
(9.) ANNUAL STATEMENT OF WORK: *(Briefly summarize the annual SOW to the extent that the project is identifiable. Include specific tasks where appropriate and helpful.)*	Monitoring activities described above are ongoing and scheduled to continue. Analysis of the November 2004 high-flow test data is scheduled to continue into FY2006. Completion of the initial phase of suspended-sediment transport model development is scheduled to be completed in FY2005 with continued refinement in FY2006. Water quality model development to continue with scheduled completion of the water temperature component in FY2006. Several USGS data reports and several peer-reviewed interpretive reports are to be completed during FY2006.
(10.) PROGRESS STATEMENT: *(Describe how each task identified in the AWP was/was not met and summarize initial findings and final results. Include a description of any significant deviation from the AWP Scope of Work.)*	Sediment-transport data collected during FY2006 on the tributaries to the CRE have been processed, finalized, and delivered to the GCMRC. Sediment-transport data collected during FY2006 on the mainstem Colorado River are now in the final stages of being processed and will be delivered to the GCMRC by March 2007. Other QW data collected during FY2006 are now in the final stages of being processed and will be delivered to the GCMRC by March 2007. Substantial progress has been made on (1) posting the real-time sediment-transport data collected under this project to the World-Wide-Web, and (2) serving these data through Oracle; these two tasks will be completed during mid 2007. The two-way satellite telemetry system is now considered operational. Updates of the mass-balance sediment budgets have been computed and delivered to the GCMRC; these have been delivered to the TWG and AMWG. The final reports from the sediment-transport modeling component of this project have been delivered to the GCMRC. During FY 2006, results from the downstream IQW project were presented at

	(1) the 2005 Fall Meeting of the American Geophysical Union, San Francisco, California, December 5-9, 2005; and (2) 8th Federal Inter-Agency Sedimentation Conference, Reno, Nevada, April 2-6, 2006.
(11.) REPORTS/PRODUCTS COMPLETED: *(Include all deliverables identified in the AWP that have been completed and report on all products beyond those deliverables identified. Include reports, presentations, poster sessions, exhibits, databases, workshops, maps, website contributions, decision support systems, newsletters, etc.)*	Presentations were made to the TWG on May-24-25, 2006 on the results from the 2004 BHBF test and the results from the development and evaluation of "High-Resolution Monitoring of suspended-sediment concentration and grain size in the Colorado River using laser-diffraction instruments and a three-frequency acoustic system." A presentation was made to the TWG on August 2-3, 2006, on the results of studies of sand transport during steady and low-fluctuating flows. Topping gave an invited lecture on June 8, 2006, at the USGS-WRD Central Region Science Workshop, Lakewood, Colorado, presentation entitled "Collection of more accurate high-resolution sediment-transport data using laser diffraction and multi-frequency acoustic instruments" The following dissertation, five papers and two abstracts were either published during FY2006 or are currently in press. Grams, P.E., 2006, Sand transport over a coarse and immobile bed: The Johns Hopkins University, unpublished Ph.D. thesis, 163 p. Melis, T.S., Jain, S., Topping, D.J., Pulwarty, R.S., and Eischeid, J.K., 2005, Critical climate controls and information needs for the Glen Canyon Adaptive Management Program and environmental assessment in the Grand Canyon region: EOS, Transactions, American Geophysical Union, v. 86, n., 52, p. F627. Topping, D.J., Rubin, D.M., Schmidt, J.C., Hazel, J.E., Wright, S.A., Melis, T.S., and Kaplinski, M., 2005, Comparison of sediment-transport and bar-response results from the 1996 and 2004 controlled-flood experiments on the Colorado River in Grand Canyon: EOS, Transactions, American Geophysical Union, v. 86, n., 52, p. F906. 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. Topping, D.J., Wright, S.A., Melis, T.S., and Rubin, D.M., 2006, High-resolution monitoring of suspended-sediment concentration and grain size in the Colorado River using laser-diffraction instruments and a three-frequency acoustic system: CD-ROM Proceedings of the 8th Federal Inter-Agency Sedimentation Conference, Reno, Nevada, April 2-6, 2006, ISBN 0-9779007-1-1. Topping, D., Rubin, D., and Melis, T., in press, Coupled changes in sand grain size and sand transport driven by changes in the upstream supply of sand in the Colorado River: Relative importance of changes in bed-sand grain size

	and bed-sand area: Sedimentary Geology. Topping, D.J., Wright, S.A., Melis, T.S., and Rubin, D.M., in press, High-resolution measurements of suspended-sediment concentration and grain size in the Colorado River in Grand Canyon using a multi-frequency acoustic system: Proceedings of the Tenth International Symposium on River Sedimentation, August 1-4, 2007, Moscow, Russia. Wiele, S.M., Wilcock, P.R., and Grams, P.E., in press, Reach-averaged sediment routing of a canyon river: Water Resources Research.
(12.) REPORTS/PRODUCTS PLANNED: *(See above, but report those items that are in progress and include expected delivery dates.)*	A manuscript by Grams and Wilcock entitled "Equilibrium transport of fine sediment over a coarse immobile bed" was submitted to the AGU journal Water Resources Research during 2006 and is currently being revised. The annual water-year 2006 data report is being finalized by the USGS-WRD Arizona Water Science Center (AWSC) and will be available during spring 2007. A USGS Open-File Report describing the 1991 suspended-sediment data-collection program on the Colorado River at National Canyon has been authored by Hornewer and others. A USGS Data-Series Report describing the water-temperature data collected in the CRE by GCES and GCMRC during the 1980s and 1990s has been authored by Voichick and Wright. Both of these two USGS reports have been reviewed and are to be published during spring 2007. A two-part article by Topping and others entitled "Evaluation of conventional sampling, laser diffraction, and acoustics for measuring suspended-sediment concentration and grain size 1. Errors associated with conventional depth-integrated sampling *and* Evaluation of conventional sampling, laser diffraction, and acoustics for measuring suspended-sediment concentration and grain size 2. Development and evaluation of a laser-acoustic system" is to be submitted to the Journal of Geophysical Research in summer 2007.
(13.) RECOMMENDATIONS: *(Describe recommendations for continuation or modification of project, other studies, or activities resulting from findings of this project; recommendations for MRP changes or future program guidance, etc.)*	This project has been adopted as core monitoring and will be reviewed as such during spring/summer 2007.

(14.) FY2006 BUDGET REPORT			**FINANCIAL INFORMATION COLLECTION DATE:**		09/30/2006
FY PLANNED GROSS BUDGET:		$ 817,947	**FISCAL YEAR NET AVAIL BAL:**		$ 764,562
COMMENTS: *(Discuss anomalies in the budget; expected changes; anticipated carryover; etc.)*	None at this time.		**FISCAL YEAR EXPENDITURES:**		$ 698,660
			FISCAL YEAR OBLIGATIONS:		$ 65,902
			END OF FISCAL YEAR AVAILABLE BALANCE:		**$ 00**
SIGNATURE: (Must be signed or submitted by PM / PI.)	/S/ Theodore S. Melis	**TITLE:**	Physical Sciences Program Manager	**DATE:**	02/03/2007