Glen Canyon Dam Adaptive Management Program Fiscal Year 2008 Budget and Annual Work Plan

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Prepared by

Bureau of Reclamation
Upper Colorado Regional Office
Salt Lake City, Utah

and

U.S. Geological Survey
Southwest Biological Science Center
Grand Canyon Monitoring and Research Center
Flagstaff, Arizona

Draft prepared for Technical Work Group Review
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U.S. Department of the Interior
U.S. Geological Survey

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Introduction

The Glen Canyon Dam Adaptive Management Program (GCDAMP) is a science-based process for continually improving management practices related to the operation of Glen Canyon Dam (GCD) by emphasizing learning through monitoring, research, and experimentation. The U.S. Geological Survey's (USGS) Grand Canyon Monitoring and Research Center (GCMRC) has responsibility for the scientific monitoring and research of the GCDAMP. GCMRC staff worked cooperatively with GCDAMP participants to identify the scope, objectives, and budget for the monitoring and research projects for fiscal year 2008 (FY08) presented in the Grand Canyon Monitoring and Research Center Fiscal Year 2008 Budget and Annual Work Plan (AWP). As was the case in FY07, the AWP for FY08 is a transitional plan designed to fund the GCDAMP Science Program for 1 year while consideration is given to the development of the Long-term Experimental Plan (LTEP), a science and funding plan for a temperature control device (TCD), and the development of a recovery program for the humpback chub (*Gila cypha*) (HBC) in Grand Canyon. Beginning in FY09, the expectations is that biennial work plans (BWP) will be developed as noted below. Other major components of the science planning process include:

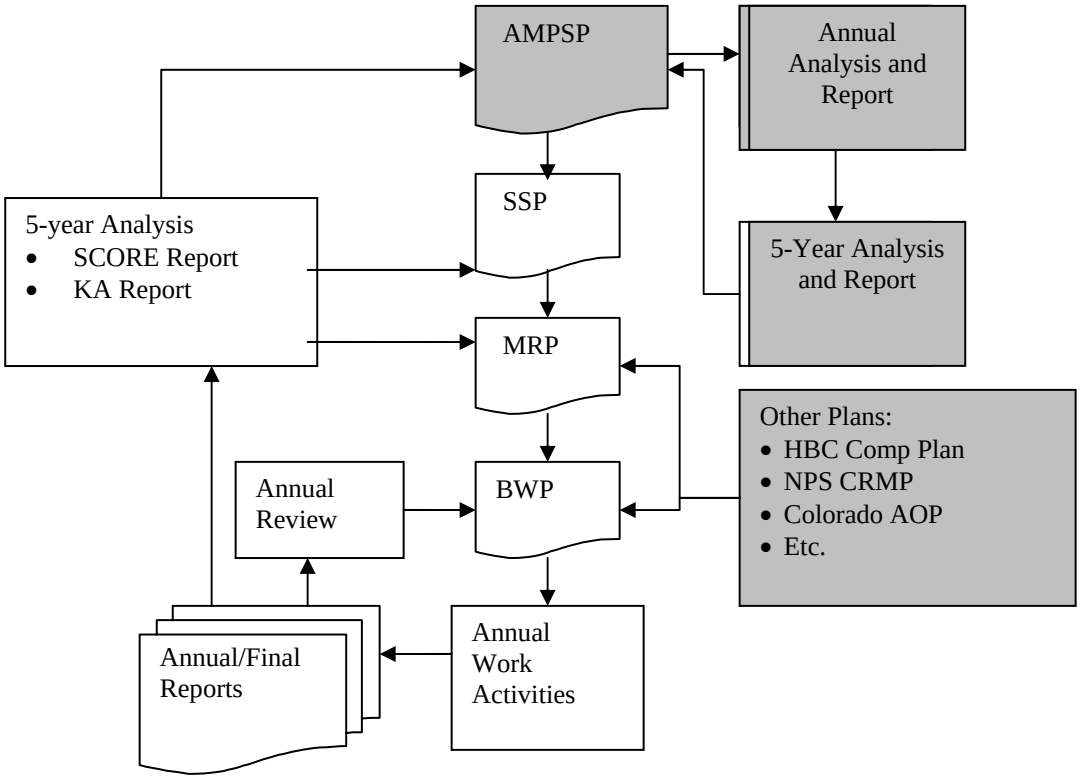
1. The Final Draft **Glen Canyon Dam Adaptive Management Program Strategic Plan (AMPSP):** A long-term plan drafted by GCDAMP participants in cooperation with GCMRC that identifies the Adaptive Management Work Group's (AMWG) vision and mission statement, principles, goals, management objectives, information needs, and management actions.

2. The **GCMRC Strategic Science Plan (SSP):** Developed by GCMRC in cooperation with GCDAMP participants to identify strategies for providing science information during a 5-year period to respond to goals, management objective, and priority questions of the GCDAMP participants, consistent with the AMPSP. The SSP was approved by the Secretary of the Interior in May 2006.

3. The **GCMRC Monitoring and Research Plan (MRP):** Developed by GCMRC in cooperation with the GCDAMP to specify research and monitoring activities for the next 5 years consistent with the strategies and priorities in the SSP. The MRP identifies the objectives associated with each strategic science question and related monitoring, experimental research, and research and development projects. The November 14, 2006, draft of the MRP was approved as a working document by the AMWG in December 2006 to help guide the development of the FY08–FY09 work plan for the GCDAMP.

Figure 2.1 depicts the flow of information in the science planning and implementation process. Annually, GCMRC will report on accomplishments related to projects included in the biennial work plan and evaluate how science has advanced knowledge relative to GCDAMP goals and management objectives. At 5-year intervals, GCMRC shall formally synthesize new scientific information in the form of an updated The State of the Colorado River ecosystem in Grand Canyon (SCORE) report (Gloss and others, 2005). In addition, the Knowledge Assessment Report (KAR) (Melis and others, 2006) will be revised to identify knowledge gaps related to the effects of various treatments/management actions on resources of interest to the GCDAMP (e.g., the effect of dam operations on humpback chub recruitment). Information from the Knowledge Assessment (KA) will be used to identify key strategic questions associated with priority GCDAMP information needs or questions. Priority information needs and science questions will be evaluated by scientists and managers to determine what revisions to the science program are needed. This includes development of revised SSP and MRP documents and a new experimental research plan. The BWP will be updated annually to address new information needs and to develop new work plans for the second year of the 2-year planning cycle. All these activities will be carried out collaboratively by scientists and GCDAMP participants. Involvement will be provided through the AMWG, Technical Work Group (TWG), appropriate ad hoc groups, and the Science Advisors Board (SAB).

Figure 2.1. Collaborative science planning and implementation process. The Glen Canyon Dam Adaptive Management Program and Department of the Interior have lead responsibility for the shaded boxes. The Grand Canyon Monitoring and Research Center has lead responsibility for the boxes not shaded.



Purpose

The purpose of the AWP is to describe the core monitoring, long-term experimental, research and development, and other related activities that will be implemented in FY08 to address priority goals, questions, and information needs specified by the GCDAMP.

Overview of the GCMRC Strategic Science Plan and Monitoring and Research Plan

The AWP is designed to implement and be consistent with the draft GCMRC SSP and MRP dated May 5, 2006, and June 21, 2006, respectively. The principal elements of the MRP and SSP that that are addressed by the FY08 AWP include:

Adaptive Environmental Assessment and Management (AEAM) Approach: The GCMRC science program will be based on the AEAM approach to natural resources management that was developed by Hollings (1978) and Walters (1985) and articulated in the AMPSP.

Collaborative Science Planning Process: GCMRC will use the planning process described above and illustrated in figure 2.1 to develop and update science plans and related work plans.

GCDAMP's Priority Strategic Science Questions: GCDAMP priority questions and the associated strategic science questions provide the primary (but not exclusive) basis for designing the science program (Appendix A).

Interdisciplinary Integrated River Science: Increased emphasis will be provided on employing an interdisciplinary, integrated science approach over the next 5 years. Principal elements of this approach involve:

- Aligning GCMRC staffing/organization to facilitate integrated, interdisciplinary science
- Enhancing the Colorado River conceptual ecosystem model to identify critical ecosystem interactions and data gaps
- Initiating an effort to gather and evaluate baseline data and develop modeling capabilities to assist in planning and evaluating a proposed GCD TCD

Bridging Science and Management: The GCMRC will develop and implement a collaborative plan/assessment among scientists and GCDAMP participants to improve the effectiveness of the GCDAMP and better integrate the use of scientific information into the GCDAMP process. The plan/assessment will address (1) the feasibility of developing/using decision-support tools to facilitate integration of scientific information in the science planning and GCDAMP decision-making processes including resource tradeoff assessments, and (2) strategies/approaches for improving the effectiveness of the GCDAMP process. In FY08, the GCMRC will convene a workshop for scientists and GCDAMP participants to develop an action plan for addressing priority issues, needs, or opportunities related to the effectiveness of the GCDAMP, and the use of scientific information in the GCDAMP process.

Overview of Annual Work Plan and Budget

The FY08 AWP was developed based on the Monitoring and Research Plan to Support the Glen Canyon Dam Adaptive Management Program (AMP). In December 2006, the Adaptive Management Work Group (AMWG) approved the MRP as a working document to help guide the preparation of the FY08–FY09 work plan and budget.

The proposed budget provides for the continued implementation of projects included in the approved Glen Canyon Dam Adaptive Management Program Fiscal Year 2007 Annual Budget and Work Plan.

The only new projects identified in FY08 are:

- The Grand Canyon archaeological site treatment plan ($300,000 in the Bureau of Reclamations portion of the budget)
- The long-term sediment storage monitoring project, which will be reviewed by the TWG for core monitoring status ($95,000)

To achieve a balanced budget, a number of projects had to be scaled back to accommodate the increased funding being requested for the new projects noted above and for other non-discretionary increases in costs for continuing projects.

Several new projects that were identified in the MRP to start in FY08 will need to be deferred because no funding was available after the continuing projects were funded. This includes:

1. Expanding/updating the conceptual ecosystem model
2. Hiring a visiting ecosystem scientist to pursue specific integrated ecosystem science strategies
3. Compilation and analysis of existing recreation safety data (deferred from FY07)
4. Evaluation of the relative importance and effects of different flows on the recreation experience

Unfunded projects identified in the MRP should be the highest priority for any discretionary funds that may become available in FY08.

In addition, the MRP identified several new initiatives to be undertaken in FY08 to address priority research and monitoring information needs in areas outside of the Colorado River ecosystem. These projects, which were proposed for funding by U.S. Geological Survey (USGS) or other non-AMP sources, include:

1. Lake Powell modeling and data synthesis
2. Little Colorado River gaging, water quality/quantity synthesis, and contaminant risk assessment
3. Climate change and drought effects on Glen Canyon Dam operations

USGS funding to address these needs was not included in the president’s proposed FY08 budget request, and therefore, these activities are not included in the FY08 AWP.

The FY08 AWP does not account for GMCRC's support for the development of the Long-term Experimental Plan environmental impact statement (EIS). The FY08 work plan may need to be adjusted after the Bureau of Reclamation provides more detailed direction on the scope of GCMRC involvement in the EIS.

Table 2.1 summarizes core monitoring, research and development, and experimental activities in the FY08 annual work plan for the GCMRC. Activities address GCDAMP goals 1–11, including related science questions and information needs. Priority and related strategic science questions are paraphrased from the Draft GCMRC Strategic Science Plan (Appendix A) and the core monitoring information needs developed by the Science Planning Group (SPG). Three categories of activities are identified:

1. **Core Monitoring Activities:** Core monitoring is consistent, long-term, repeated measurements using scientifically accepted protocols to measure status and trends of key resources. Core monitoring activities are those that have been pilot tested for one to several years, undergone a protocol evaluation panel (PEP) evaluation and peer review, and have been formally approved by the GCDAMP for core monitoring status. In FY08, the monitoring activities associated with the status of humpback chub in the Little Colorado River and mainstem Colorado River are scheduled for PEP evaluation by GCMRC and the TWG for core monitoring status

2. **Research and Development Activities**: Activities aimed at (1) addressing specific hypotheses or information needs related to a priority GCDAMP resource(s) and/or (2) developing/testing new technologies or monitoring procedures. Examples of research and development (R&D) activities in the FY08 work plan include:

   - Link whole-system carbon cycling to food webs in the Colorado River—the project that will provide the basis for the food base monitoring program
   - Investigate new, more-effective technologies for sampling fish populations such as remote passive integrated transponder (PIT) tag reading technology, sonic tag technology
   - Advanced development of downstream flow, temperature, and suspended-sediment models
   - Evaluate quality of historical remote sensing imagery for change detection

3. **Experimental Activities**: A suite of flow and non-flow treatments and/or management actions designed to improve conditions of target resources (humpback chub, sediment, etc.) while allowing for an understanding of the relationship between treatments/management actions and the target resources. The LTEP has yet to be finalized by the GCDAMP. Several long-term experimental options are currently being evaluated by the Bureau of Reclamation pursuant to the National Environmental Policy Act in coordination with the GCDAMP. The LTEP will be implemented following issuance of a Record of Decision in FY09.

Table 2.1. Summary of core monitoring, research and development, and experimental activities in the fiscal year 2008 (FY08) annual work plan for the Grand Canyon Monitoring and Research Center (GCMRC). Several long-term experimental options currently under discussion are not reflected in the table; additional experimental options will be developed upon approval by the U.S. Department of the Interior. Activities address Glen Canyon Dam Adaptive Management Program (GCDAMP) goals 1–12 in relation to science questions and information needs. Priority and related strategic science questions are paraphrased from the Draft GCMRC Strategic Science Plan (Appendix A). Information needs are paraphrased from the GCDAMP Strategic Plan. Abbreviations are as follows: SSQ=strategic science question, CMIN=core monitoring information need, RIN=research information need, and SA=GCDAMP Science Advisors summary questions.

GCDAMP goal	Priority science questions and information needs (Questions from Strategic Science Plan and Monitoring and Research Plan in italics)	Core monitoring activities	Experimental activities	Research and development activities
1. Food base	AMWG Priority:1, 3, and 5 *SSQ 1-5. What are the important pathways that link lower trophic levels with fish and how will they link to dam operations?* *SSQ 1-6. Are fish populations, trends, or indicators from fish, such as growth, condition, and body composition, correlated with patterns in invertebrate flux?* *SSQ 5-2. Is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations?*			FY06–FY09: Determine carbon budget to understand how energy is exchanged among organisms in the Colorado River; develop monitoring techniques and metrics for key organisms FY08: Diet, drift, and predation data analysis
2. Humpback chub (HBC) and other native fishes (A.)	AMWG Priority:1, 3, and 5 *SSQ 1-1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of young-of-year (YoY) and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?* *SSQ 1-4. Can long-term decreases in abundance rainbow trout be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species.* CMIN 2.1.2 Determine and track abundance and distribution of all size classes of HBC in the LCR and the mainstem.	FY07–FY08: Monitor status and trends of HBC in Little Colorado River (LCR) and mainstem using existing protocols		FY06 and ongoing: Stock assessment FY07–FY08: Gear efficiency/sampling evaluation FY07–FY11: Statistical review of existing HBC monitoring protocols and habitat data FY07–FY11: Evaluate protocols for warmwater and coldwater nonnative fish monitoring, removal, and control; effects on native fish

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GCDAMP goal	Priority science questions and information needs (Questions from Strategic Science Plan and Monitoring and Research Plan in italics)	Core monitoring activities	Experimental activities	Research and development activities
2. Humpback chub and other native fishes (B.)	AMWG Priority:1, 3, and 5 *SSQ 1-2. Does a decrease in the abundance of rainbow trout and other coldwater and warmwater nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile humpback chub to the adult population?* *SSQ 1-4. Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action?* *SSQ 5-6. Do the potential benefits of improved rearing habitat (warmer, more stable, more backwater and vegetated shorelines, more food) outweigh negative impacts due to increases in nonnative fish abundance?* CMIN 2.4.1 Determine and track the abundance and distribution of nonnative predatory fish species in the CRE and their impacts on native fish. RIN 2.4.1: What are the most effective strategies and control methods to limit nonnative fish predation and competition on native fish? RIN 2.4.3: To what degree, which species, and where in the system are exotic fish a detriment to the existence of native fish through predation or competition?	FY07–FY08: Continue mainstem monitoring of fish community		FY07–FY10: Develop and test nonnative fish management plan FY07–FY11: Develop abundance estimation framework that allows scientists to better estimate nonnative fish numbers in mechanical removal reaches FY07–FY10: Develop bioenergetic model to predict changes in fish communities in response to environmental changes
2. Humpback chub and other native fishes (C.)	AMWG Priority:1, 3, and 5 *SSQ 1-1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of YoY and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?* *SSQ 1-7. Which tributary and mainstem habitats are most important to native fishes and how can these habitats best be made useable and maintained?* SA 1. What are the most limiting factors to successful HBC adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?			FY07–FY10: Review data and literature on HBC in upper basin to see if HBC habitat can be identified, protected, and re-created below GCD

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GCDAMP goal	Priority science questions and information needs (Questions from Strategic Science Plan and Monitoring and Research Plan in italics)	Core monitoring activities	Experimental activities	Research and development activities
2. Humpback chub and other native fishes (D.)	AMWG Priority:1, 3, and 5 *SSQ 1-8. How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling?*			FY07–FY09: Develop alternative, noninvasive HBC monitoring gear to reduce stress on fish (e.g., DIDSON camera, remote PIT tag reading, and sonic tags) FY07–FY09. Evaluate the effects of trammel net sampling
3. Extirpated species		No projects	FY07–FY11: Evaluation and planning of temperature control device	No projects
4. Rainbow trout (RBT)	AMWG Priority: 3 *SSQ 3-6: What Glen Canyon Dam operations (ramping rates, daily flow range, etc.) maximize trout fishing opportunities and catchability?* CMIN 4.1.2 Determine annual proportional stock density of rainbow trout in the Lees Ferry reach. CMIN 4.1.4 Determine annual standard condition (Kn) and relative weight of rainbow trout in the Lees Ferry reach.	FY07–FY11: Monitor status and trends of Lees Ferry BRT population FY08: Review/evaluate RBT monitoring for core monitoring status		
5. Kanab ambersnail (KAS)	AMWG Priority: 3 CMIN 5.1.1 Determine and track the abundance and distribution of KAS at Vasey's Paradise. CMIN 5.2.1 Determine and track the size and composition of the habitat used by KAS at Vasey's Paradise.	FY08: KAS habitat monitoring.		

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GCDAMP goal	Priority science questions and information needs (Questions from Strategic Science Plan and Monitoring and Research Plan in italics)	Core monitoring activities	Experimental activities	Research and development activities
6. Springs /riparian	AMWG Priority: 4 *SSQ 2-1. Do dam controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?* *SSQ 3-2. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs?* CMIN 6.1.1., 6.6.1., 6.2.1., 6.5.1. Determine and track the abundance, composition, distribution, and area of terrestrial native and nonnative vegetation species in the CRE.			FY08: Terrestrial monitoring FY08 and ongoing: Terrestrial mapping FY07–FY11: Vegetation synthesis project
7. Quality-of-water	AMWG Priority:1, 3, and 5 *SSQ 3-5. How is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations?* *SSQ 5-1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and near shore water temperatures throughout the CRE)?* *SSQ 5-3. To what extent do temperature and fluctuations in flow limit spawning and incubation success for native fish?* CMIN 7.3.1. What are the status and trends of water quality releases from Glen Canyon Dam?	FY07–FY09: Lake Powell monitoring using existing protocols FY07–FY11: Downstream integrated quality-of-water monitoring (including suspended-sediment flux)		FY07–FY11: Advanced development of downstream flow, temperature, and suspended-sediment models

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8. Sediment *(fine and coarse sediment)*	*AMWG Priority: 1,2,3, and 4* *SSQ 4-1. Is there a "Flow-Only" operation (i.e. a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal time scales?*	FY07–FY11: Implementation of recommendations from the final SEDS-PEP (summer 2006) FY08: Fine Sediment "SED TREND" monitoring - Detection of trends in lower elevation channel sand deposits through annual reach-scale topographic measurements of sand-storage between suspended-sediment flux monitoring stations. In FY08, the reach between river mile 0and 30 will be mapped using multi-beam acoustic bathymetry methods for comparison with 2000-01 measurements. FY08: Coarse Sediment – No core monitoring activities are scheduled at present until the next remote sensing overflight occurs in FY09.		FY07–FY11: Map change in nearshore habitat resulting from 2004 BHBF; convert exiting overflight analog images to digital to facilitate research

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GCDAMP goal	Priority science questions and information needs (Questions from Strategic Science Plan and Monitoring and Research Plan in italics)	Core monitoring activities	Experimental activities	Research and development activities
9. Recreation (A)	AMWG Priority: 3 and 4 *SSQ 3-9. How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?* CMIN 9.3.1. Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons.	FY07–FY11: Monitor change in sandbar campable area, topography, and volume (see above, project linked to sandbar monitoring)		FY07–FY08: Complete campsite inventory and GIS atlas FY07–FY08: Evaluate use of field data vs. remotely sensed data for campable area monitoring
9. Recreation (B)	AMWG Priority: 3 *SSQ 3-7. How do dam controlled flows affect visitors' recreational experiences, and what is/are the optimal flows for maintaining a high quality recreational experience in the CRE?* *SSQ 3-8. What are the drivers for recreational experiences in the CRE, and how important are flows relative to other drivers in shaping recreational experience outcomes?* *SSQ 3-10. How can safety and navigability be reliably measured relative to flows?* *SSQ 3-11. How do varying flows positively or negatively affect visitor safety, health and navigability of the rapids?* *SSQ 3-12. How do varying flows positively or negatively affect group encounter rates, campsite competition, and other social parameters that are known to be important variables of visitor experience?*			FY08: Compile and analyze existing safety data
10. Hydropower	AMWG Priority: 3 *SSQ 3-3. What are annual hydropower replacement costs of the MLFF since 1996?* *SSQ 3-4. What are the projected hydropower costs associated with the various alternative flow regimes being discussed for future experimental science (as defined in the next phase of experimental design)?* CMIN 10.1.1. Determine and track the marketable capacity and energy produced through dam operations in relation to the various release scenarios (daily fluctuation limit, upramp and downramp limits, maximum flow limit of 25,000 cfs minimum flow limit of 5,000 cfs).	FY07–FY11: Monitor power generation and market values under current and future dam operations		

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GCDAMP goal	Priority science questions and information needs (Questions from Strategic Science Plan and Monitoring and Research Plan in italics)	Core monitoring activities	Experimental activities	Research and development activities
11. Cultural	AMWG Priority:2, 3, and 4 *SSQ 2-1. Do dam controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites in the CRE, and if so, how?* *SSQ 2-4. How effective are various treatments (e.g., check dams, vegetation management, etc.) in slowing rates of erosion at archaeological sites over the long term?* *SSQ 2-7. Are dam controlled flows affecting TCPs and other tribally-valued resources, and if so, in what respects?* CMIN 11.1.1 Determine the condition and integrity of archaeological sites and TCPs in the CRE through tracking rates of erosion, visitor impacts, and other relevant variables. (SPG revised CMIN) CMIN 11:2.1 Determine the condition of traditionally important resources and locations using tribal perspectives and values. (SPG revised CMIN)			FY08: Research and development towards core monitoring (development of protocols for archaeological sites and TCPs) FY08: Implement Technical Work Group (TWG) approved tribal monitoring projects
12. High-quality monitoring, research, and adaptive management program (A.) Data acquisition, storage, and analysis	AMWG Priority:1,2, 3, 4, and 5	FY07–FY11: Remote sensing activities related to the preparation, acquisition, and storage of 2009 terrestrial resource monitoring data	No projects	FY07–FY11: Convert existing analog images (especially overflight imagery) and reports to digital (see also goal 8) FY07–FY11: Shoreline habitat and change detection mapping (see goals 2 and 8)

A summary of the anticipated FY08 funding by funding source is provided in table 2.4 and figure 2.3 summarizes GCMRC's FY08 budget by GCDAMP goal. A breakout of the projects included as part of goal 12 is summarized in figure 2.4. The budget for each project in the work plan is included in the project descriptions and summarized for the entire budget in the separate budget attachment.

Table 2.3. Projects and activities included in the FY08 AWP associated with GCDAMP goal 12 (i.e., maintain a high-quality monitoring, research, and adaptive management program).

1. Data acquisition, storage, and analysis
   - Remote sensing data acquisition (bank funding for FY09 acquisition)
   - Maintain, update, and enhance Oracle database
   - Conversion of analogy data (report and imagery) to digital format
   - GIS support
   - Library support
   - Map shoreline habitat changes over a 5-year period
   - Survey operations support
2. Logistical support for field activities/river trips
3. Develop work plan for enhancing the conceptual ecosystem model
4. Workshop to develop and action plan for improving GCDAMP effectiveness
5. Administrative support for GCMRC
6. GCMRC program planning and management
7. Independent peer review and science advisor support
   - GCDAMP effectiveness workshop follow-up
   - Risk assessment of LTEP Alternatives
   - Review/assess integrated, interdisciplinary science approaches
   - 2008 science symposium
8. Southwest Biological Science Center information technology support

Figure 2.3. Budget breakout of Grand Canyon Monitoring and Research Center FY08 budget by Glen Canyon Dam Adaptive Management Program (GCDAMP) goal 12.

This is a place holder to be completed by June 18

Table 2.4. Total anticipated funding to support the GCMRC in fiscal year 2008 (FY08).

This is a place holder to be completed by June 18

Figure 2.4. Budget for Implications of Experimental vs. Non-Experimental Scenarios

This is a place holder to be completed by June 18

Project Descriptions

Detailed descriptions of each activity included in the AWP are described in the following section. Activities are presented based on the GCDAMP goal they are designed to address. Activities included in the AWP will be carried out in an integrated, interdisciplinary fashion. Integration efforts are described as an element of each description below.

Since its inception, the GCDAMP has attempted to ensure appropriate science program continuity and balance across all goals adopted by the program. The current focus of the GCDAMP is on strategic science questions associated with high priority AMWG information needs. Other GCDAMP goals will still be pursued, but with less intensity until priority issues of concern are resolved and monies can be reprogrammed or obtained through alternative sources. The AWP, with the exception of GCDAMP goal 3 (restore extirpated species), includes at least one activity to address each GCDAMP goal.

GCDAMP Goal 1: Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels.

BIO 1.R1.08: Aquatic Food Base

Start Date

September 2005

End Date

September 2009

Principal Investigator(s)

Robert Hall, Ph.D., Aquatic Biologist, University of Wyoming; Emma Rosi-Marshall, Ph.D., Aquatic Biologist, Loyola University, Chicago; Colden Baxter, Ph.D., Fisheries Biologist, Idaho State University; and Theodore Kennedy, Ph.D., Aquatic Biologist, Grand Canyon Monitoring and Research Center

Geographic Scope

Systemwide, with monthly sampling at accessible sites (Glen Canyon, ~river mile (RM) -15–0, and Diamond Creek, ~RM 225) and quarterly sampling at less accessible sites (Marble Canyon, ~RM30; below Little Colorado River (LCR) confluence, ~RM61; Randy's Rock, ~RM126; and below Havasu Creek, ~RM163). Three of these sites are known humpback chub aggregations.

Project Goals/Tasks

The overall goal of this project is to determine the role that food is playing in the distribution, condition, and abundance of fishes throughout the entire system. Quantifying the density and production of basal resources (i.e., algae, terrestrial leaf litter, etc.) and invertebrates will determine the amount of energy that is available to support production of fishes. Trophic basis of production calculations, where the types and amounts of different food items eaten by invertebrates and fishes are quantified, will determine the relative contribution of basal resources, invertebrates, and other food items to fish production. The results of this work will establish the degree to which native fishes are limited by food resources, by either low production at the base of the food web or via shunting of energy to nonnative animals such as New Zealand mudsnails or rainbow trout. This information, in turn, provides guidance to managers considering various management options.

The objectives that are addressed by this project are:

- Determine the important energy sources and pathways that support fishes, especially native species and trout

- Quantify the abundance of basal resources using a carbon budget framework to determine potential available energy for higher trophic levels
- Identify composition and quantity of drifting organic matter and invertebrates
- Incorporate knowledge into bioenergetics model and trophic basis of production calculations
- Develop core monitoring strategies for the aquatic food base in the Colorado River from Glen Canyon Dam to Diamond Creek

Need for Project

The aquatic protocol evaluation panel (PEP) (Anders and others, 2001) and Science Advisor (Palmer, 2004) review of food base monitoring and research both recommended major changes in the GCMRC food base program. Specifically, Anders and others (2001) recommended that:

> "The food base program needs to be critically reviewed because the current level of understanding about the linkages between lower trophic levels and food availability of native fishes is not adequate to interpret food base data in relation to the management goal."
>
> "Since there are scientific as well as statistical uncertainties associated with any approach for study[ing] the relation of food base to trends in abundance of fish populations the best approach is likely a fully integrated one, utilizing data on the abundance of prey available to fish in the GCE, the apparent food habits as indicated by stomach content analysis, and indicators from the fish themselves, including isotopes, growth and condition, and body composition."
>
> "Because the food habits of specific life stages of most native species are not well known, a broad look at the potentially available food is required for a monitoring program. The best indicator of potential energy available is a measure of production – both primary and secondary – which is a measure of organic matter creation over time (mass/area/time)."

These recommendations formed the basis for the food base request for proposals (RFP) released by GCMRC in May 2005. The research proposal submitted by Dr. Hall and others that was awarded a cooperative agreement by GCMRC closely followed the recommendations laid out in the PEP and SA reviews and the food base RFP. GCMRC continues to lead and monitor the project progress.

Strategic Science Questions

Primary SSQ addressed:

> **SSQ 1-5.** What are the important pathways, and the rate of flux among them, that link lower trophic levels with fish and how will they link to dam operations?

Additional SSQs addressed:

> **SSQ 1-6.** Are trends in the abundance of fish populations, or indicators from fish such as growth, condition, and body composition (e.g., lipids), correlated with patterns in invertebrate flux?

SSQ 5-2. How is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations?

Links/Relationships to Other Projects

Physical Sciences

Four of our six study reaches are fine-grained integrated sediment transport (FIST) and integrated water-quality (IWQ) monitoring sites. We will use bathymetry, bed-classification, sediment transport, and water quality data to determine how the physical environment affects the standing mass, distribution, and production of basal resources and invertebrates. We will work closely with the Physical Science and Modeling Program, relying on their infrastructure and capabilities, to estimate inputs of organic matter from the Paria River during base flow and flooding events. Finally, the temperature model that is being developed by the Physical Science and Modeling Program will be a valuable tool for estimating systemwide growth rates of algae and invertebrates because temperature is an important determinant of algae and invertebrate growth rates.

Fisheries

Ongoing fisheries monitoring data on the distribution and relative density of common native and nonnative fishes will be used to determine rates of energy flow to fishes in the system. Where possible, we will also rely on existing fisheries monitoring efforts to obtain the fish stomachs and tissue samples required for gut content and stable isotope analysis, respectively.

Terrestrial Resources

Ongoing vegetation mapping efforts will be used to estimate rates of allochthonous inputs to the mainstem Colorado River, a potentially significant basal resource supporting invertebrate and fish growth.

Information Needs Addressed

This project focuses on quantifying food availability, and determining which food resources are most important to invertebrates and fishes, in the Colorado River ecosystem (CRE) in Glen and Grand Canyons. The distribution of multiple sampling sites over multiple years will allow a number of research information and core monitoring information needs to be directly addressed, as enumerated below: (research information need (RIN), core monitoring information need (CMIN))

Primary information needs addressed:

RIN: 1.1. What are the fundamental trophic interactions in the aquatic ecosystem?

RIN 1.4. What is the current carbon budget for the Colorado River ecosystem?

Other information needs addressed:

CMIN 1.2.1. Determine and track the composition and biomass of benthic organisms between Glen Canyon Dam and the Paria River in conjunction with measurements of flow, nutrients, water temperature, and light regime.

CMIN 1.3.1. Determine and track the composition and biomass of primary producers below the Paria River.

General Methods

Quantify Basal Resources Using a Carbon Budget Framework

That is, quantify inputs, standing stock, and transport of organic matter throughout the river. (RIN 1.4)

- Primary production and ecosystem respiration will be quantified using whole stream metabolism calculations: Use diel changes in dissolved oxygen concentration, a byproduct of algal photosynthesis, to determine rates of algae production for mile long reaches of the river. Use nighttime sags in dissolved oxygen concentration to determine ecosystem respiration, a measure of basal resource (both leaf litter and algae) consumption. If quantity of carbon consumed during respiration exceeds quantity of carbon produced by algal photosynthesis, this indicates allochthonous inputs may be an important basal resource fueling the aquatic food web. Data collected monthly at Glen Canyon and Diamond Creek and four times per year along the river corridor.

- Allochthonous inputs: allochthonous inputs originate from riparian vegetation, tributaries, and Lake Powell. Allochthonous inputs from riparian vegetation have been quantified by Ralston and Kennedy (unpublished manuscript). Use ISCO automated water samplers (only at Paria River and LCR) to collect samples of fine organic matter during flooding events. We will also sample coarse organic matter on the Paria River during flooding events using large plankton nets. Collections also occur monthly on the Paria River and four times per year at major downstream tributaries. Water samples and plankton nets will be used to quantify the concentration of dissolved nutrients, dissolved organic matter, and plankton coming from Lake Powell. Samples will be collected monthly.

- Standing stocks: the standing stock of algae and organic matter will be quantified using a Hess sampler and by scraping algae off rocks. These data will provide a measure of basal resource availability within each reach. Collections will occur monthly at Glen Canyon and Diamond Creek and four times per year at downstream locations.

- Transported organic matter and invertebrates: The amount of organic matter and invertebrates transported into and out of each reach will determine the extent to which downstream reaches are linked to upstream processes. Depth integrated water samples will be used to quantify transported organic matter and invertebrates.

Determine Important Trophic Pathways Linking Basal Resources with Fishes

- Stable isotope and diet analysis of invertebrates and fish. Collect diet information from gut content studies of invertebrates and fishes. Collect standards of food items (e.g., algae, benthic invertebrates,

terrestrial invertebrates) for signatures for use in stable isotope analysis. Samples collected four times per year along the river corridor.

Determine Flux along Trophic Pathways

- Invertebrate density, production, and growth measurements. Sample all benthic habitats (i.e., cobble bars, cliff faces, boulders, talus slopes, sandy bottom, etc.) to quantify density of invertebrates. Habitat specific density estimates will be made using shoreline and bed-classification data from the Physical Science and Modeling Program. Growth measurements for the most common invertebrates (e.g., New Zealand mudsnails, Gammarus, chironomids, simuliids) in controlled chambers. Production of invertebrates will be calculated using density estimates coupled with growth measurements. Invertebrate density will be estimated monthly at Glen Canyon and Diamond Creek and four times per year at downstream locations. Growth measurements will be taken four times per year at Glen Canyon and Diamond Creek.
- Fish density and production estimates. Density estimates for small-bodied and juvenile fishes will be determined quarterly using the multi-pass depletion method. Density estimates for larger bodied fishes will be derived using existing fisheries monitoring data. Production estimates will be attempted using existing fisheries data and literature values.
- Bioenergetics modeling and trophic basis of production calculations. Invertebrate and fish production data will be coupled with diet information (derived from both gut content and stable isotope analysis) to determine the relative contribution of basal resources to invertebrate and fish production.

Products/Reports

Publications

We anticipate at least six publications in peer-review journals will be produced during this project. Tentative subjects for these publications include:

- Measuring air-water gas exchange and whole-system metabolism in a large, regulated river (proof of concept paper)
- Seasonal and spatial variation in organic matter inputs to the Colorado River, Grand Canyon (synthesis paper of metabolism, allochthonous inputs, lake inputs, tributary inputs, etc.)
- Spatial variation of secondary production of invertebrates in the Colorado River
- Spatial variation in the relative importance of basal resources to invertebrate and fish production in the Colorado River
- Linking whole-river carbon flows with food webs in the Colorado River
- Impacts of New Zealand mudsnails on invertebrate and fish production in the Colorado River

Reports

A final report summarizing major results and recommendations will be submitted by December 2009.

Monitoring Protocols

A report describing potential monitoring protocols will be submitted at the close of the project. Some potential monitoring tools that will be evaluated during the course of the project include:

- Measurement of primary production and ecosystem respiration using whole stream metabolism methods
- Production measurements of significant invertebrate taxa (e.g., Gammarus, simuliids, and New Zealand mudsnails)
- Fish diet analysis
- Organic and invertebrate drift measurements

Budget

BIO 1.R1.08	
Aquatic Food Base (FY08–FY09)	
	Fiscal Year 2008

BIO 1.R3.08: Diet, Drift, and Predation Data Analysis

Start Date

February 2007

End Date

March 2008

Principal Investigator(s)

Colden Baxter, Ph.D., Fisheries Biologist, Idaho State University, and Michael Yard, Ph.D., Fisheries Biologist, Idaho State University.

Geographic Scope

The mechanical removal reaches of the mainstem Colorado River, river mile (RM) 50–70.

Project Goals/Tasks

This project uses diet and drifting organic matter data collected in 2002 and 2003 to support the following objectives:

- Determine the important energy sources and pathways that support fishes, especially trout
- Identify variable food availability in the drift (flux) along trophic pathways
- Incorporate knowledge into bioenergetics model and trophic basis for production calculations
- Document primary production and drift of fish food items in response to varying flow regimens

Rainbow and Brown Trout Diet Analysis

The purpose of this study was to describe quantitatively the diet proportions (density and weight) of rainbow trout and brown trout, and determine if biotic and environmental factors influenced food resource use patterns. Objectives were to determine if there were differential use of prey items (fish and invertebrates), item sizes, and abundance (biomass and density). Additional objectives were to determine if differential use of food resources were due to interactions from differences between biotic and physical factors. These factors included differences among prey and predator densities, predator and prey size differences, food resource availability, flow discharge, and suspended sediment loads. Diet analysis was also to include specific indexes representing electivity, diet overlap and diet breadth between rainbow trout and brown trout.

Food Resource Availability

Drift samples collected concurrent with fish removal efforts provided a means for determining density and biomass estimates of prey items available to foraging fish. Results from this analysis were to be used as part of food electivity which characterized food resource use in relation to availability. Other study objectives were to determine if food resource availability differed spatially and/or temporally due to variability in seasonal production, flow discharge, and sediment discharge.

Incidence of Piscivory

The primary goal of this study was to better understand fish interactions occurring among different environmental factors that potentially contribute to predatory behavior within and among different fish species, sampling periods, and spatial strata. The biotic factors include differences in prey and predator densities, predator and prey size-classes, and food resource availability. Physical factors include differences in flow, water clarity, and temperature.

To assess and account for the separate effects associated with mechanical treatments, as well as the natural variability occurring in the ecosystem, large sample sizes were required to determine if diet composition and mean incidence of predation varied significantly among sampling trips, seasons, and years.

Specific tasks completed to date are field work, sample enumeration and biomass determination, and data entry. However, these data have not been assessed for data omission, data entry errors, or data completely compiled into a database design. Only preliminary analysis has been conducted to date and results have not been documented in the form of reports or manuscripts. Therefore, this proposal identifies separate tasks required to complete each of the three study projects. A sequential order is suggested for completing each of the necessary tasks, specific to each project. Tasks will include database development, data entry, literature search, data analysis, manuscript development, and documentation of metadata (see methods, below).

Need for Project

Over the past two decades, research has been directed toward understanding causal mechanisms limiting the phytobenthic community (aquatic food base), and more recently monitoring these resource trends in the CRE (Blinn and others, 1995; Shaver and others, 1997; Benenati and others, 1998). Although this bottom-up perspective has provided greater understanding of resource availability, very little dietary use information is known (although often presumed) (Maddux, 1987; McKinney, 1999) regarding the utilization of different food resources by the higher trophic levels (Shannon and others, 2000). In this ecosystem the importance of aquatic food resources has been implicitly recognized; however, it remains uncertain whether or not the availability of aquatic as well as terrestrial invertebrates are spatially and/or temporally limited in their availability to higher trophic levels.

Interactions with nonnative fish are implicated in the decline and extinction of native fishes throughout the Colorado River Basin (Tyus and Saunders, III, 2000). The cumulative effect from piscivory is known to structure fish communities, especially species that have been compromised by changes in habitat and demographic characteristics that result in low abundance and recruitment levels (e.g., *Gila cypha*, humpback chub). While it is difficult to determine what is the primary factor most responsible for the decline in humpback chub recruitment (Coggins and others, 2006), negative interactions (predation and competition) with nonnative coldwater salmonids such as rainbow trout (*Onchorhynchus mykiss*) and brown trout (*Salmo trutta*) are one possible factor that is scientifically testable.

An experimental manipulation was used to test the nonnative fish predation/competition hypothesis. Trout were mechanically removed from selected reaches near the Little Colorado River inflow area. This mechanical removal study had multiple study projects. Over a 2-year period (2003–4), approximately 16,000 fish were caught and assessed for the incidence of predation. Diet and drifting organic matter were both sampled. Sampling design, field collection, processing, and preservation methods used are explained in greater detail by Coggins and others (2002, 2003).

This proposal has been specifically developed to provide a 1-year approach that completes study projects that were designed to assess nonnative fish diet utilization and food resource availability to provide a better understanding of predatory and possible competitory interactions with native fishes.

Strategic Science Questions

SSQ 1-5. What are the important pathways, and the rate of flux among them, that link lower trophic levels with fish and how will they link to dam operations?

SSQ 1-6. Are trends in the abundance of fish populations, or indicators from fish such as growth, condition, and body composition (e.g., lipids), correlated with patterns in invertebrate flux?

Links/Relationships to Other Projects

How the available aquatic food base is utilized by fishes is important for managers to understand as they consider various flow regimens. A more complete understanding of fish diets will help managers decide what primary and secondary production should be targeted as management scenarios are considered. Results of this project will support management of the rainbow trout population as a sport species below Glen Canyon Dam and as a predator/competitor in Grand Canyon.

Information Needs Addressed

Primary information need addressed:

RIN 1.1. What are the fundamental trophic interactions in the aquatic ecosystem?

Diet analysis of rainbow and brown trout will provide a comprehensive look at what fish are eating in the system.

Other information need addressed:

RIN 1.5.3. How has the value and availability of drift as a food source for humpback chub changed with the implementation of Record of Decision (ROD) operations?

Drift samples will be compared with data from Valdez and Ryel (1995) also collected at the LCR confluence, to determine whether value and availability has changed with implementation of Record of Decision.

General Methods

Database Development

Presently these data exists as a series of separate files (Microsoft® Excel) found in spreadsheet form. These files are currently archived at GCMRC. Data contained in spreadsheets need to be imported into a common database (Microsoft® Access), and relationally linked to other field collection data (locality, sampling period, and sample bottle number). These data need to be checked for data entry errors, duplications, relational links, and omissions. Data omissions will be determined by conducting a series of cross-comparisons with sample bottle numbers against common fields in the GCMRC fish database containing data from the mechanical trout removal study. This linkage is critical in relating specific data (species, size, sex, location, and date) to stomach contents. Identified errors will be resolved by reentry of data from original data sheets.

Data Entry

Preliminary assessment of data entry efforts for the incidence of piscivory indicates that data entry is only partially complete (60%) for this project. This will require determining which sample data are missing for specific sampling periods, locating the appropriate data sheets, and entering the data. Estimated time required for this task is identified in the summary budget.

Literature Search

This project will be initiated with a comprehensive review of the most current literature. The time and costs required for conducting the search, review process, and photocopying appropriate publications are identified in the summary budget under other direct costs.

Data Analysis

The selected contractor will have limited use of available statistical software (SAS, Inc.) currently licensed at GCMRC to conduct appropriate statistical analysis. This approach will result in a net savings to GCMRC because the purchase of additional software will not be necessary.

Products/Reports

Draft Manuscript Development

A draft manuscript will be developed and subjected to peer review in April 2008. The budget includes costs to prepare the submittal draft and to modify the report in accordance with reviewers' comments.

Metadata Completion

Final data will be transferred to GCMRC in Microsoft® Access database structure. Documentation of field collection methodologies and analysis will be developed as well as information concerning data fields. These are to be provided to GCMRC as specified in their standard metadata format structure.

Budget

BIO 1.R3.08	
Diet, Drift and Predation Data Analysis	
	Fiscal Year 2008

GCDAMP Goal 2: Maintain or attain viable populations of existing native fish, remove jeopardy from humpback chub and razorback sucker, and prevent adverse modification to their critical habitat.

BIO 2.R1.08: Little Colorado River Humpback Chub Monitoring Lower 15 km (HBC Population Estimates)

BIO 2.R2.08: Little Colorado River Humpback Chub Monitoring Lower 1,200 m

BIO 2.R3.08: Humpback Chub Monitoring Above Chute Falls

Start Date

Ongoing

End Date

Ongoing

Principal Investigator(s)

U.S. Fish and Wildlife Service (FWS) leads BIO 2.R1.08 and BIO 2.R3.08 with support from GCMRC (M.E. Andersen, L.G. Coggins, staff). Arizona Game and Fish Department (AZGFD) leads BIO 2.R2.08 with support from GCMRC (M.E. Andersen, L.G. Coggins, staff).

Geographic Scope

Little Colorado River (LCR)

Project Goals/Tasks

- Elucidate critical physical and biotic factors that may be limiting to, or supportive of, the humpback chub and other native fish populations in Grand Canyon. Seek methods that reduce, eliminate, or control limiting factors.
- Identify habitat characteristics that are most important to all life stages of humpback chub. Seek methods that maintain, and possibly replicate, suitable habitats.
- Determine and refine the most appropriate method(s) for estimating the population size of humpback chub and other Grand Canyon fishes, including sampling design, gear selection, and development of remote monitoring methods. The method(s) developed and selected should be consistent with the

second edition of the Colorado River Endangered Fishes Recovery Goals. (The FWS has scheduled revision of the goals to be initiated in 2007.)

- Improve understanding of dam operations on young-of-year (YoY) and juvenile HBC survival and habitat use.
- Establish core monitoring protocols for HBC in Grand Canyon.

The specific goal of the suite of tasks identified in this project description is to provide current evaluations of the HBC population in the LCR. The specific projects that will be conducted in FY08 are:

- Population estimate of HBC in the LCR
- Monitor HBC above Chute Falls
- Monitor HBC in lowest 1,200 meters of LCR

Specific objectives include:

1. Obtain population estimates of HBC ≥ 150 mm and ≥ 200 mm in the lower 15 km of the LCR and in the LCR above Chute Falls
2. Provide other information related to physical parameters of the LCR (i.e., temperature and turbidity), length frequency data, community composition, sexual condition and characteristics of native fish (sex, ripe, tuberculate, etc.), frequency of external parasites (i.e., primarily *Lernaea cyprinacea*), and predation
3. Collect data in support of stock asessment models (e.g., mark-recapture tagging data, length frequency data)

Need for Project

Because the LCR is the primary tributary where young HBC are produced, a rigorous stock assessment of this endangered species is needed to allow managers to assess the condition of the population and its response to management actions. These projects will conduct this assessment in FY08. Reviews by peer scientists, statistical data analysis, and historical review of existing data will provide the basis for directing how monitoring of HBC will be conducted in future years. A protocol evaluation panel (PEP) will be convened to address this issue and core monitoring needs in FY08.

Strategic Science Questions

Primary science question addressed by these projects:

- **SSQ 1-1.** To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of YoY and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?

Additional science question addressed by these projects:

- **SSQ 1-2.** Does a decrease in the abundance of rainbow trout and other cold and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile HBC to the adult population?

The Glen Canyon Dam Adaptive Management Program's (GCDAMP) Science Advisors have summarized the strategic science questions with the following question (the projects outlined here specifically address the question, especially their evaluation of annual spawning success):

- **SA 1.** What are the most limiting factors to successful HBC adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?

Links/Relationships to Other Projects

Humpback chub are the only remaining member of the genus *Gila* inhabiting the Colorado River between Glen Canyon Dam (GCD) and Grand Wash Cliffs. This species was the listed as endangered by the FWS in 1967 and is protected under the Endangered Species Act of 1973. Humpback chub distribution in Grand Canyon has been characterized as occurring in discrete locations or aggregations (Valdez and Ryel, 1995). Of these nine aggregations (30 Mile, RM 29.8–31.3; LCR Inflow, RM 57–65.4; Lava Canyon to Hance, RM 65.7–76.3; Bright Angel Creek Inflow, RM 83.8–92.2; Shinumo Creek Inflow, RM 108.1–108.6; Stephen Aisle, RM 114.9–120.1; Middle Granite Gorge, RM 126.1–129.0; Havasu Creek Inflow, RM 155.8–156.7; and Pumpkin Spring, RM 212.5–213.2), only the LCR inflow is recognized as a population in that it consistently demonstrates some level of successful recruitment (Kaeding and Zimmerman, 1983; Valdez and Ryel, 1995; Gorman and Stone, 1999). The current paradigm is that the remaining eight aggregations exist as a result of either downstream transport of juvenile HBC from the LCR Inflow aggregation, or relict fish (30 Mile population) produced in years immediately following construction of Glen Canyon Dam (Valdez and Ryel, 1995). However, limited movement between the LCR Inflow and both the 30 Mile and Havasu Creek Inflow aggregations has been observed.

Improvement of the status of the HBC will be necessary for the species to be considered for down listing or delisting. The GCDAMP can contribute to an improved status for HBC, thereby decreasing the amount of effort required of the GCDAMP on behalf of this species. The most recent iteration of the recovery goals for this species, now scheduled for review and revision beginning in 2007, required a minimum of 2,100 adults in the Grand Canyon, a steady or increasing trend in the population, and control of environmental threats, among other requirements. One potential element of conservation of HBC in Grand Canyon may be a GCD flow release regimen that supports this species. These flows can be expected to impact many of the elements of the canyon resources, including sediment, cultural resources, and recreation. Therefore, releases that benefit one resource, HBC in this example, must be consistent with conservation of other resources. Conservation of LCR resources, especially water and protection from catastrophic events, whether accomplished through the GCDAMP process or by other means, would be important not only to protecting the spawning HBC population in the LCR but other organisms found there.

Information Needs Addressed

The primary information needs addressed by these projects are:

CMIN 2.1.2 Determine and track recruitment (identify life stage), abundance, and distribution of HBC in the LCR.

CMIN 2.1.1. Determine and track year class strength of HBC between 51–150 mm in the LCR and the main channel.

General Methods

Annual Spring (March and April) HBC Abundance Assessments in the Lower 15 km of the LCR

This monitoring effort provides relative abundance assessments of the spawning and resident populations of humpback chub in the LCR below Chute Falls. It will be conducted concurrent with mainstem sampling to provide a more ideal sampling design in support of model refinement and use and stock assessment. Hoop nets are deployed to capture fishes for this effort. Evaluation of relative trends of other fishes, especially native bluehead suckers (BHS) and flannelmouth suckers (FMS), is a desirable side benefit of this sampling. Relative abundances of nonnative fishes in the LCR are also developed from this sampling.

Annual Fall (September and October) HBC Abundance Assessments in the Lower 15 km of the LCR

This program has been ongoing since 2000 and annually produces assessments of the abundance of HBC > 150 mm total length (TL) (Coggins and Van Haverbeke, 2001; Van Haverbeke and Coggins, 2003; Van Haverbeke, 2003; Van Haverbeke, 2004). The fall sampling is aimed primarily at providing an estimate of the abundance of sub-adult fishes rearing in the LCR. These efforts rely on multiple event mark-recapture analysis of passive integrated transponder (PIT) tag data to produce abundance estimates using closed population models. In FY08 these data will be combined with concurrent mainstem sampling (see above) results to support use of the age-structured mark recapture (ASMR) model to assess humpback chub population numbers. Two 12-day trips into the LCR are conducted to collect the data used to construct these estimates in the fall (September and October). Sampling is predominantly conducted using hoop nets evenly distributed throughout the lower 15 km of the LCR. Other types of sampling gear are not used in the LCR because they have been shown to be less efficient at capturing HBC > 150mm total length (TL) in the LCR.

Annual Spring Relative Abundance Assessment in the Lower 1,200 m of the LCR

This program was established by the AZGFD in 1987 and has operated continuously through 2004 with the exception of the years 2000–1 (Ward and Persons *In Review*). This program annually produces assessments of the relative abundance (i.e. catch per unit effort; CPUE) of all size classes of HBC, FMS, BHS, speckled dace (SPD), and a host of nonnative fishes in the lower 1,200 m of the LCR. Data is collected during a 30–40 day period in spring (April and May) using hoop nets set in standardized locations distributed throughout the reach. In general, this effort represents the longest and most consistent relative abundance dataset available to infer trends in the LCR HBC population. Importantly, it provides an independent comparison to the mark-recapture based assessments. The statistical power of this portion of the monitoring program has not yet been assessed, but statistically significant differences in relative abundance are apparent in current data.

Above Chute Falls

Two trips are conducted above Chute Falls in the LCR to initiate a stock assessment program of translocated individuals, and potential offspring. These trips will occur during late May when the LCR discharge is at base flow to provide an annual abundance estimate of HBC within this region. In addition to the annual population

estimates, this data can be incorporated into open population models for HBC being developed at USGS GCMRC. Moreover, because we have and will continue to implant these fish with PIT tags (Biomark, Inc.), it is likely that some individuals will eventually be recaptured in the lower LCR corridor and/or Colorado River, which would increase our knowledge of migration patterns.

During the LCR trip, personnel will reside at the established translocation camp located at 16.2 rkm on Navajo lands. This camp has an established helicopter landing pad and offers high ground protection from most floods. Baited hoop nets (0.5–0.6 m dia., 1.0 m length, 6 mm mesh, single 10 cm throat) will be set from shorelines to capture and PIT tag HBC as part of a mark-recapture program to estimate the abundance of individuals ≥ 150 mm in the upper 13.6 km of the LCR.

Personnel will be responsible for fishing baited hoop nets in the LCR corridor above Chute Falls (13.6 rkm) which is the upstream extent of the current downstream LCR monitoring. Approximately 50 hoop nets will be fished throughout this upper reach from 13.6 rkm to 18.0 rkm with the average spacing between nets approximately 100–150 m. Each hoop net will be positioned in favorable habitat suspected of yielding good catches of HBC. Nets will be repositioned as needed. On average, each hoop net will be checked once every 24 hours. Each net will be baited near it's cod end by attaching a nylon mesh bag (30 x 30 cm, 6 mm mesh) containing AquaMax^{TM} Grower 600 for Carnivorous Species (Purina Mills Inc., Brentwood, MO). All captured HBC will be examined for a colored elastomer tags and PIT tags. Those individuals not previously PIT tagged, but have obtained sufficient sizes to be tagged without injury, will be held overnight either offshore in an aerated tank or in the LCR in a secured holding pen to allow time for digestion of any consumed bait, whereby they will be tagged and released.

The overall reach will be broken down into two sub-reaches and each sub-reach fished for 3 days. The upper reach designation will be from 18.0 to 15.0 rkm (undesignated point below Blue Spring to 1st travertine dam above Chute Falls). Currently 18 rkm is the highest point in which HBC have been located above Chute Falls. The lower sub-reach will extend from 15.0 to 13.6 rkm (1st dam above Chute Falls to Lower Atomizer Falls where lower LCR monitoring begins). The lower sub-reach is relatively small because of the time constraints needed to maneuver around major travertine dams so that we can sufficiently sample the myriad of adult HBC habitats (deep pools, large boulders, etc.) existing within this sub-reach. In addition to fishing baited hoop nets and PIT tagging HBC as detailed above, personnel will be responsible for the following tasks:

- Measure and record the fork and total lengths, sex, sexual condition, and sexual characteristics for all captured native fishes (except speckled dace)
- Measure and record the total length, sex, and sexual condition of all other captured fish
- Record the stomach contents of all captured large-bodied nonnative fish except common carp
- Record the location, shoreline habitat, hydraulic unit, and set and pull time, and map locations for each hoop net set
- Take daily turbidity with the Hach 2100 turbidimeter, water temperature measurements, and CO_2 using titration

Management Plan

Once the initial stock assessment has been completed, FWS will draft a management plan that will direct any future management action above Chute Falls. This document will evaluate the benefits or disadvantages of

additional translocations and, if possible, provide a trigger for when additional movements of fish should be performed.

Quality Control

Quality control relative to data delivery will be assured through the use of standardized data collecting, recording, and electronic entry procedures. These include use of standardized fish handling protocols, field data collection forms, and computerized data entry routines. Additionally, various automated summary reports of submitted data are being developed to aid in identifying errors in electronic versions of submitted data. Copies of original field data sheets are held by the GCMRC library so that future problems encountered with fish databases may be checked against field data sheets. Electronic copies of data are submitted to GCMRC on a CD/DVD format. Data must meet GMCRC data standards.

Analysis of the Little Colorado River Monitoring Program

The value of four LCR sampling occasions, monitoring above Chute Falls, and monitoring of the lower 1,200 m of the LCR will be included in the 2008 PEP regarding monitoring of the Grand Canyon humpback chub population.

Products/Reports

The FWS delivers two trip reports annually, including data collected, to GCMRC. The trip reports are summarized and analyzed in a final report delivered to GCMRC in January of the following year. These reports address the lower 15 km monitoring and the monitoring above Chute Falls.

The AZGFD delivers one annual report on the results of their lower 1,200 m monitoring to GCMRC.

A report addressing the current statistical rigor of the sampling methods in the LCR will be produced by October 2008. Program and external review of the sampling for HBC in the LCR will be conducted in FY08. Any recommended and accepted monitoring changes will be implemented in FY09.

Budget

BIO 2.R1.08	
LCR HBC Monitoring Lower 15 km (HBC Population Estimates; Ongoing)	
	Fiscal Year 2008

BIO 2.R2.08	
LCR HBC Monitoring Lower 1,200 m (Ongoing)	
	Fiscal Year 2008

BIO 2.R3.08	
HBC Monitoring Above Chute Falls (Ongoing)	
	Fiscal Year 2008

BIO 2.R4.08: Monitoring Mainstem Fishes

Start Date

Ongoing

End Date

Ongoing

Principal Investigator(s)

Arizona Game and Fish Department (AZGFD) with support from GCMRC (M.E. Andersen, L.G. Coggins, staff).

Geographic Scope

The mainstem Colorado River in Grand Canyon between Lees Ferry and upper Lake Mead

Project Goals/Tasks

The objectives that are addressed by this project are:

- Determine and refine the most appropriate method(s) for estimating the population size of humpback chub (HBC) and other Grand Canyon fishes, including sampling design, gear selection, and development of remote monitoring methods. The method(s) developed and selected should be consistent with the second edition of the Colorado River Endangered Fishes Recovery Goals. (The FWS has scheduled revision of the goals to be initiated in 2007).
- Improve understanding of dam operations on young-of-year (YoY) and juvenile humpback chub survival and habitat use.
- Establish core monitoring protocols for humpback chub in Grand Canyon.
- Monitoring of small-bodied fishes (native and nonnative species) in backwater habitats is conducted in conjunction with monitoring of Kanab ambersnail (BIO 5.R1.08)

The goals of this project are to provide status and trend information on the abundance and recruitment of the fish community in Grand Canyon. It is one of the projects that will be the subject of a protocol evaluation panel (PEP) in FY09.

Need for Project

Native fish populations in Grand Canyon are key resources of concern influencing decisions on both the operation of Glen Canyon Dam (GCD) and other non-flow related actions. To inform these decisions, it is imperative that accurate and timely information on the status of fish populations, particularly the endangered HBC, are available to managers. A suite of adaptive experimental management actions are being contemplated to

better understand the mechanisms controlling the population dynamics of native fishes, and to identify policies that are consistent with the attainment of management goals. The assessments generated from this project provide a baseline from which to assess the effects of implemented experimental actions. This information is therefore crucial to: 1) inform the program as to attainment of identified goals, 2) provide baseline status and trend information to be used as a backdrop to further understand mechanisms controlling native fish population dynamics, and 3) evaluate the efficacy of particular management policies in attaining program goals. The results of this project are potentially useful in assessing changes to Federal Endangered Species Act (ESA) listing status of native fishes in the Colorado River.

Strategic Science Questions

The primary science question addressed by this project is:

> **SSQ 1-1.** To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning, and incubation in the mainstem, survival of YoY and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?

Additional science questions addressed by this project are:

> **SSQ 1-4.** Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species.
>
> **SSQ 1-8.** How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling?

The Adaptive Management Program Science Advisors have articulated the following summary science questions that are addressed by this project:

> **SA 1.** What are the most limiting factors to successful HBC adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?
>
> **SA 2.** What are the most probably positive and negative impacts of warming the Colorado River on HBC adults and juveniles?

Links/Relationships to Other Projects

Understanding the factors influencing the dynamics of the Grand Canyon native fish populations, especially the endangered HBC, is important to evaluating the effects of management and conservation activities, especially GCD operations. To discover these factors, a combination of large scale manipulations (e.g., experimental removal of nonnative fish or long-term implementation of contrasting flow regimes) and smaller scale process oriented research (e.g., assessment of juvenile fish growth rates under various temperature regimes or availability of particular food items) will likely prove most efficient in determining the key mechanisms regulating native fish populations. In each of these endeavors, it is critical that baseline trends in population abundance and recruitment are known. It is only with this knowledge that it is possible to assess population level impacts of large scale

manipulations. Though it is informative to assess the effects of experimental management on processes thought to be important like growth or survival at particular life stages, this is not ultimately sufficient to determine efficacy of particular management actions. Linkages between these processes and ultimate recruitment to populations must be established. Again, these linkages can only be made if baseline trends in population abundance and recruitment are available.

Information Needs Addressed

The primary information needs addressed by this project are:

> **CMIN 2.1.2.** Determine and track year abundance and distribution of all size classes of HBC between in the LCR and the mainstem.
>
> **RIN 2.4.2.** Determine if suppression of nonnative predators and competitors increases native fish populations.

The mainstem sampling described in this project description will provide an evaluation of the trend of HBC abundance, especially those greater than 150 mm, through calculation of catch per unit effort. Humpback chub who are identified by a passive integrated transponder (PIT) tag provide catch data to the age-structured mark recapture (ASMR) model, further supporting evaluation of abundance for this species. Mainstem hoop net sampling, shown to be of value for assessing catch rates of humpback chub, especially those less than 150 mm, during the mechanical removal project (2003–6) will be employed to help address science questions regarding success or failure of humpback chub to recruit in the mainstem. It will be valuable to compare the results of mainstem sampling for smaller size classes to the same results from the LCR for evaluation of year class survivorship in the mainstem.

General Methods

Mainstem fish monitoring, including the monitoring below Diamond Creek, has used electrofishing to provide an overall view of the status and trends of native and nonnative fishes in the Colorado River between Lees Ferry and Lake Mead. The electrofishing gear is not without its limitations, particularly its lack of effectiveness at sampling deep water habitats. However, it remains the most important tool for providing an overall assessment of the mainstem fish community and its use will be retained in FY08. Two mainstem electrofishing trips will be conducted, one during March and again in September. The September trip will also include sampling below Diamond Creek. Concurrent with LCR sampling in the spring (March and April), two mainstem monitoring trips utilizing trammel nets and hoop nets will be conducted to capture and tag humpback chub in the LCR Inflow reach. These data as well as data collected during the spring LCR sampling efforts will be used to conduct a concurrent closed population mark-recapture estimate of humpback chub abundance. This monitoring sampling design will be assessed as part of the PEP scheduled for 2008.

Products/Reports

Annual reports detailing the findings of each of the above activities is prepared and submitted to GCMRC for internal and/or external review as center policy dictates. As warranted, project findings are prepared and submitted for publication in the primary peer-reviewed literature. These data will be utilized in the 2008 PEP.

Budget

BIO 2.R4.08	
Monitoring Mainstem Fishes (includes Diamond Down; Ongoing)	
	Fiscal Year 2008

BIO 2.R5.08: Nonnative Control Planning

BIO 2.R6.08: Nonnative Control Pilot Testing

Start Date

September 2007

End Date

September 2011

Principal Investigator(s)

GCMRC (K.D. Hilwig, M.E. Andersen, L.G. Coggins, staff) in cooperation with U.S. Fish and Wildlife Service (FWS) and Arizona Game and Fish Department (AZGFD)

Geographic Scope

The Colorado River ecosystem in Grand Canyon

Project Goals/Tasks

The objectives addressed by these projects are:

- Elucidate critical physical and biotic factors that may be limiting to, or supportive of, the humpback chub and other native fish populations in Grand Canyon. Seek methods that reduce, eliminate, or control limiting factors.
- Determine and refine the most appropriate method(s) for estimating the population size of humpback chub and other Grand Canyon fishes, including sampling design, gear selection, and development of remote monitoring methods. The method(s) developed and selected should be consistent with the second edition of the Colorado River Endangered Fishes Recovery Goals. (The FWS has scheduled revision of the goals to be initiated in 2007.)

The specific goal of the tasks identified in this project description is to evaluate threats to native fishes resulting from nonnative fishes, to develop a plan to control those species that pose the greatest threats to natives, and to test implementation of this plan. This project is expected to be complete in September 2011.

Need for Project

Nonnative fishes are among the greatest threats to native fishes in western North America rivers. Nonnative fishes may threaten native fishes by direct predation, by competing for available food and other resources, and by habitat modification. Nonnative fishes were introduced into Grand Canyon not later than early in the twentieth century. While native fishes survived these initial introductions at least long enough to be described by early researchers, other system stressors, especially the modification of natural flows as a result of dam installation, appear to have increased the threats to native fishes from nonnative fishes.

The GCDAMP has recognized nonnative fishes as a threat that needs to be addressed, and preceded with implementation of a rainbow trout and other nonnative fish control experiment around the Little Colorado River (LCR) inflow reach over the last 4 years. The work described in this work plan builds on that effort. As the Colorado River mainstem becomes warmer due to climate effects, the potential for increased threat from warm water adapted nonnative fishes increases. There is an immediate need to begin investigating what species pose the greatest threats to natives, how those species might be controlled, and to test control approaches for efficacy.

Strategic Science Questions

The primary science questions addressed by these projects are:

> **SSQ 1-2.** Does a decrease in the abundance of rainbow trout and other cold and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile humpback chub to the adult population?
>
> **SSQ 1-4.** Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species.
>
> **SSQ 5-6.** Do the potential benefits of improved rearing habitat (warmer, more stable, more backwater and vegetated shorelines, more food) outweigh negative impacts due to increases in nonnative fish abundance?

The Adaptive Management Program Science Advisors have articulated the following summary science questions that are addressed by this project:

> **SA 1.** What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?
>
> **SA 2.** What are the most probably positive and negative impacts of warming the Colorado River on humpback chub adults and juveniles?

Links/Relationships to Other Programs

Understanding the status and trends of the Grand Canyon fish populations, especially the endangered humpback chub, is important to evaluating the effects of management and conservation activities, especially Glen Canyon Dam (GCD) operations. If humpback chub populations are stable or increasing, then dam operations are unlikely to be having a negative effect on the population, and may be supporting population stability and growth. If the populations are decreasing, the operations may be having a negative impact and may need to be critically evaluated, along with other physical and biotic factors, especially nonnative fish populations.

One of the management approaches that have been proposed to support humpback chub and other native fishes in Grand Canyon is the installation of selective withdrawal structure (SWS) on the GCD so that water of various temperatures, especially warmer water from the reservoir's epilimnion, may be released. A potential concern with this approach is that warmer mainstem temperatures may also favor warmer water nonnatives, increasing the risk from these species to natives. This project will help address the potential threat from nonnatives and how it may be addressed, thereby helping evaluate the impact of the SWS.

Information Needs Addressed

The primary information needs addressed by these projects are:

CMIN 2.4.1 Determine and track the abundance and distribution of nonnative predatory fish species in the Colorado River.

RIN 2.4.1. What are the most effective strategies and control methods to limit nonnative fish predation and competition on native fish?

RIN 2.4.3. To what degree, which species, and where in the system are exotic fish a detriment to the existence of native fish through predation or competition?

RIN 2.4.4. What are the target population levels, body size, and age structure for nonnative fish in the Colorado River ecosystem that limit their levels to those commensurate with the viability of native fish populations?

General Methods

A project manager was hired in October 2007 to begin working on this project full time. She is reviewing relevant literature, especially the history of fish introductions in Grand Canyon, life histories, and habitat used by those species, and case histories of nonnative control in other big river systems. Currently, the manager is developing a comprehensive nonnative control plan, due for completion by September 2011 and a short-term response plan due for completion in 2007. The field study planned for 2008 will be directed by the results of the pilot project scheduled for 2007. Beginning in 2007, a brief annual progress report will be delivered which will include the results of annual control method and gear testing projects. The 2007 project will test three gear types for effectiveness at capturing channel catfish and the use of sonic tags to track channel catfish.

Products/Reports

Brief annual reports will be produced each year of the project. One experimental trip is anticipated each year. Each experimental trip will be preceded by a complete trip plan and followed by a complete trip report. These field studies will supplement literature studies to be incorporated into a comprehensive nonnative control document scheduled for completion in September 2011.

Budget

BIO 2.R5.08	
Nonnative Control Planning	
	Fiscal Year 2008

BIO 2.R6.08	
Nonnative Control Pilot Testing	
	Fiscal Year 2008

BIO 2.R7.08: Stock Assessment of Native Fish in Grand Canyon

Start Date

October 2006

End Date

Ongoing

Principal Investigator(s)

Led by GCMRC (L.G. Coggins)

Geographic Scope

The mainstem Colorado River in Grand Canyon

Project Goals/Tasks

The objective addressed by this project is to determine and refine the most appropriate method(s) for estimating the population size of humpback chub and other Grand Canyon fishes, including sampling design, gear selection, and development of remote monitoring methods. The method(s) developed and selected should be consistent with the second edition of the Colorado River Endangered Fishes Recovery Goals. (The FWS has scheduled revision of the goals to be initiated in 2007.)

The specific goals of the tasks identified in this project description are to annually update and refine stock assessment models for humpback chub, and to attempt to develop stock assessment models for flannelmouth sucker and bluehead sucker.

Need for Project

Native fish populations in Grand Canyon are key resources of concern influencing decisions on both the operation of GCD and other non-flow related actions. To inform these decisions, it is imperative that accurate and timely information on the status of native fish populations, particularly the endangered humpback chub, are available to managers. Additionally, a suite of adaptive experimental management actions are being contemplated to better understand the mechanisms controlling the population dynamics of native fishes, and to identify policies that are consistent with the attainment of management goals. The assessments generated from this project will be used, in part, to assess the effects of implemented experimental actions. This information is therefore crucial to: 1) inform the program as to attainment of identified goals, 2) provide baseline status and trend information to be used as a backdrop to further understand mechanisms controlling native fish population dynamics, and 3) evaluate the efficacy of particular management policies in attaining program goals. Finally, results from this project are potentially useful in assessing changes to Federal Endangered Species Act listing status of native fishes in the Colorado River.

Strategic Science Questions

The primary science question addressed by this project is:

> **SSQ 1-1.** To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of young-of-year (YoY) and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?

Another science question addressed by this project is:

> **SSQ 1-8.** How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling?

The Adaptive Management Program Science Advisors have articulated the following science question that is partially addressed by this project:

> **SA 1.** What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?

Links/Relationships to Other Projects

Understanding the factors influencing the dynamics of the Grand Canyon native fish populations, especially the endangered humpback chub, is important to evaluating the effects of management and conservation activities, especially Glen Canyon Dam operations. To discover these factors, a combination of large scale manipulations (e.g., experimental removal of nonnative fish or long-term implementation of contrasting flow regimes) and smaller scale process oriented research (e.g., assessment of juvenile fish growth rates under various temperature regimes or availability of particular food items) will likely prove most efficient in determining the key mechanisms regulating native fish populations. In each of these endeavors, it is critical that baseline trends in population abundance and recruitment are known. It is only with this knowledge that it is possible to assess population level impacts of large scale manipulations. Additionally, though it is informative to assess the effects of experimental management on processes thought to be important like growth or survival at particular life stages, this is not ultimately sufficient to determine efficacy of particular management actions. Linkages between these processes and ultimate recruitment to populations must be established. Again, these linkages can only be made if baseline trends in population abundance and recruitment are available.

Information Needs Addressed

The RIN most directly addressed by this project is:

> **RIN 2.2.2.** Determine if a population dynamics model can effectively predict response of native fish under different flow regimes and environmental conditions.

The activities in this project will refine and apply modeling to investigation of native and nonnative fish populations allowing for comparison with various environmental factors, including flow regimes. Other RINs that ask questions about fish responses to environmental conditions that can be partially addressed with accurate modeling of the populations include:

RIN 2.2.8. What combination of dam release patterns and nonnative fish control facilitates successful spawning and recruitment of humpback chub in the Colorado River ecosystem?

RIN: 2.2.12. What are the impacts of research activities on mortality, recruitment, and the population size of humpback chub?

RIN 2.4.2. Determine if suppression of nonnative predators and competitors increases native fish populations.

General Methods

To provide humpback chub status and trend information, the GCMRC mark recapture database will be annually updated with most recent data collected during routine monitoring efforts. Following this update, the humpback chub mark recapture database will be reanalyzed using (where appropriate) both open and closed mark-recapture based abundance estimators to provide most current information on humpback chub status and trend. In particular, we will rely heavily on the age-structured mark recapture (ASMR) models to determine trends in humpback chub abundance and recruitment. Ultimately we will consider the performance of a suite of assessment models to infer current status of the humpback chub in Grand Canyon. Finally, we will evaluate the applicability of similar techniques as described above to assessing stocks of flannelmouth sucker and bluehead sucker.

Products/Reports

Annual assessment results will be presented to the TWG/AMWG as requested via oral reports. Biennially, native fish assessments will be compiled in peer-reviewed reports.

Budget

BIO 2.R7.08	
Stock Assessment of Native Fish in Grand Canyon	
	Fiscal Year 2008

BIO 2.R8.08: Abundance Estimation Procedures

Start Date

October 2006

End Date

Ongoing

Principal Investigator(s)

Led by GCMRC (L.G. Coggins)

Geographic Scope

The mechanical removal reaches in the Colorado River in Grand Canyon

Project Goals/Tasks

The objectives addressed by this project are:

- Elucidate critical physical and biotic factors that may be limiting to, or supportive of, the humpback chub and other native fish populations in Grand Canyon. Seek methods that reduce, eliminate, or control limiting factors.
- Explore the use of alternative estimation methods to evaluate the size of nonnative fish populations in the removal reach. Refinement of these estimates allows a more precise description of the magnitude of experimental mechanical removal treatment effects and may also help to evaluate factors affecting capture probability of electrofishing methods.

The goal of this project is to evaluate the utility of Bayesian hierarchical models to estimate the abundance of nonnative fish (primarily rainbow trout).

Need for Project

Precise and unbiased estimates of the abundance of rainbow trout in the removal reaches of the Colorado River are necessary to evaluate both the magnitude and efficiency of removal efforts. These estimates allow computation of: the magnitude of the treatment effect (i.e., what percentage of nonnative fishes have been removed from the removal reach?), the efficacy of the removal program (e.g., what percentage of fish is removed with each depletion pass?), and the rate that fish immigrate back into the removal reach. In general, these estimates are the fundamental metrics of interest in the mechanical removal project.

Science Questions

The primary science question addressed by this project is:

> **SSQ 1-4.** Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species.

Links/Relationships to Other Projects

The work outlined in this project has a direct linkage to the mechanical removal project through the estimation of abundance and the other metrics described above. Additionally, deriving a general relationship between turbidity and vulnerability of fish to capture is potentially extremely useful to the electrofishing based elements of the fish monitoring program. Because our monitoring program currently relies on electrofishing catch rate to index the abundance of rainbow and brown trout, patterns in catch rate are possibly a result of both changes in abundance and turbidity induced changes in vulnerability. If it becomes possible to estimate the relationship between turbidity and vulnerability, we could essentially "correct" both the historic and future catch rate estimates to obtain a less biased index of abundance.

Information Needs Addressed

> **RIN 2.2.8.** What combination of dam release patterns and nonnative fish control facilitates successful spawning and recruitment of humpback chub in the Colorado River ecosystem?

This project contributes to resolution of this RIN by helping to quantify the number of nonnative fishes that must be removed from the system to allow rebound of HBC population numbers.

General Methods

Currently, the traditional Zippin abundance estimator is used to estimate the abundance of nonnative fish (primarily rainbow trout) in the mechanical removal reaches of the Colorado River. Though accepted and widely applied, this estimator makes the strict assumption that the vulnerability of fish among depletion passes is constant. Because large changes in turbidity are commonly observed within and among removal trips, this assumption is questionable. A more contemporary Bayesian estimation framework allows relaxation of this assumption if the relationship between a covariate (e.g., turbidity or sediment concentration) and vulnerability can be estimated. Additionally, this framework may allow more efficient use of the available data by allowing model based aggregation of site specific estimates. Program BUGS (Bayesian Inference using the Gibbs sampler) will be used to fit models to our removal data.

Products/Reports

This work will appear as part of Coggins dissertation and/or publications in the primary literature.

Budget

BIO 2.R8.08	
Abundance Estimation Procedures	
	Fiscal Year 2008

BIO 2.R9.08: Investigate Factors Affecting the Survival Rate of Juvenile Native Fishes in the Mainstem Colorado River

Start Date

October 2006

End Date

September 2010

Principal Investigator(s)

Led by GCMRC (L.G. Coggins)

Geographic Scope

The mainstem Colorado River in Grand Canyon

Project Goals/Tasks

The objectives addressed by this project are:

- Improve understanding of factors influencing survival of young-of-year (YoY) and juvenile native fishes.
- Identify habitat characteristics (biotic and abiotic) that are important to juvenile life stages of native fishes chub.

This project was titled Bioenergetic Modeling for fiscal year 2007. However, we have retitled this project to more closely describe the purpose, rather than the method, of the project. Additionally, although bioenergetic models are one potential tool to evaluate the effect of dam operations, water temperature, and biotic interactions on survival rate of young native fishes, we are also investigating the use of other models to achieve this goal.

Need for Project

Informed predictions of ecosystem responses from well constructed models to particular biotic and abiotic perturbations are useful for a number of reasons. First, they are useful as a policy screening mechanism to select potential experimental management actions or treatments that have a high probability of achieving desired resource responses, or eliminating from consideration those that have low success probability. Second, they can be used to predict consequences of unintended actions such as introduction of nonnative fishes not presently in the system. Lastly, they can be used to evaluate hypotheses about the relative importance of factors influencing the survival rate of juvenile native fish and the fish community as a whole.

Science Questions

SSQ 1-4. Can long-term decreases in abundance of rainbow trout in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species.

SA 1. What are the most limiting factors to successful humpback chub adult recruitment in the mainstem: spawning success, predation on YOY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?

Links/Relationships to Other Projects

Adaptive management, as described in the DOI handbook, requires predictive models to evaluate potential management actions or experimental policies relative to resource response and learning. These predictive models can take many forms such as bioenergetic models or more mechanistic observational models. We will attempt to use monitoring data on juvenile native fish near the mouth of the Little Colorado River to model survival rate of those fish as a function of dam operations, water temperature, and nonnative fish abundance. Additionally, we will continue to evaluate the utility of a specific kind of bioenergetic model (ecopath) to investigate linkages to all elements of the aquatic ecosystem. These linkages will foster better collaboration between terrestrial, aquatic food base, and fisheries investigations by making these linkages explicit in a common modeling framework. Using the ecosim functionality which allows policy simulations, this model could be used in a planning context at all levels of the program with regard to questions about the aquatic ecosystem.

Information Needs Addressed

RIN 2.4.2. Determine if suppression of nonnative predators and competitors increases native fish populations.

This project is aimed at providing information on the relative magnitude of dam operations, water temperature, and nonnative fish abundance on the survival of juvenile native fish in the mainstem Colorado River.

General Methods

We will construct a mechanistic model to describe the abundance of juvenile native fish in the mainstem Colorado River below the confluence of the Little Colorado River. We will populate the model with the relative abundance measurements collected during mechanical removal and select monitoring trips during 2003-2004. We will attempt to relate apparent survival of these fish to changes in dam operations, water temperature, and nonnative fish abundance. Additionally, we may populate an ecopath model (http://www.ecopath.org/) using data available from previous studies conducted in Grand Canyon as well as the relevant scientific literature to provide auxiliary information on the magnitude of mortality effects from nonnative fishes. Of particular importance will be the diet data collected associated with the mechanical removal project.

Products/Reports

This work will appear as part of Coggins dissertation and subsequent publications in the primary literature.

Budget

BIO 2.R9.08	
Investigate Factors Affecting the Survival Rate of Juvenile Native Fishes in the Mainstem Colorado River	
	Fiscal Year 2008

BIO 2.R11.08: Native Fishes Habitat Data Analysis

Start Date

October 2006

End Date

September 2010

Principal Investigator(s)

GCMRC (M.E. Andersen)

Geographic Scope

The mainstem Colorado River in Grand Canyon

Project Goals/Tasks

The objectives addressed by this project are:

- Elucidate critical physical and biotic factors that may be limiting to, or supportive of, the humpback chub and other native fish populations in Grand Canyon. Seek methods that reduce, eliminate, or control limiting factors.
- Identify habitat characteristics that are most important to all life stages of humpback chub. Seek methods that maintain, and possibly replicate, suitable habitats.
- Improve understanding of dam operations on young-of-year and juvenile humpback chub survival and habitat use.

This project will use available literature to help determine the specific habitat preferences for different life history stages of native fishes, especially the endangered HBC. The available literature, including databases, will be analyzed with multivariate statistics in order to develop indicators of what habitat characteristics are most important for HBC and other natives.

Need for Project

A great deal of peer-reviewed literature, gray literature, and database information addresses specific aspects of habitat preferences/usage by different life stages of Grand Canyon native fishes, especially HBC. Scientists and managers trying to provide GCD flow recommendations have repeatedly tried to informally assimilate and synthesize the available data, but the data remain so scattered that these attempts are difficult. It is not uncommon for different individuals, reading different literature sources, to come to different conclusions regarding what native fish in Grand Canyon need. The lack of synthetic, statistically robust information makes recommendations to dam operators less than compelling. This project initiates a multiyear effort to synthesize data and subject it to

rigorous statistical methods to help guide habitat maintenance/creation recommendations to dam operators and natural resource managers.

Strategic Science Questions

The primary science question addressed by this project is:

> **SSQ 1-1.** To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the mainstem, survival of YoY and juvenile stages in the mainstem, or by changes in growth and maturation in the adult population as influenced by mainstem conditions?

Other science questions addressed by this project are:

> **SSQ 1-7.** Which tributary and mainstem habitats are most important to native fishes and how can these habitats best be made useable and maintained?
>
> **SSQ 5-3.** To what extent do temperature and fluctuations in flow limit spawning and incubation success for native fish?
>
> **SSQ 5-4.** What is the relative importance of increased water temperature, shoreline stability, and food availability on the survival and growth of YoY and juvenile native fish?

The GCDAMP Science Advisors have articulated the following science questions that are addressed by this project:

> **SA 1.** What are the most limiting factors to successful HBC adult recruitment in the mainstem: spawning success, predation on YoY and juveniles, habitat (water, temperature), pathogens, adult maturation, food availability, competition?
>
> **SA 2.** What are the most probably positive and negative impacts of warming the Colorado River on HBC adults and juveniles?

Links/Relationships to Other Projects

Understanding the status and trends of the Grand Canyon fish populations, especially the endangered HBC, is important to evaluating the effects of management and conservation activities, especially Glen Canyon Dam operations. If HBC populations are stable or increasing, then dam operations are unlikely to be having a negative effect on the population, and may be supporting population stability and growth. If the populations are decreasing, the operations may be having a negative impact and may need to be critically evaluated, along with other physical and biotic factors, especially nonnative fish populations.

Because of the diversity of individuals and available literature regarding HBC and other native fishes habitat preferences, recommendations for dam operations can be diverse and are not always well supported. Well intentioned dam operators and natural resource managers often need to make decisions but currently do not have comprehensive, synthetic information available on which to base their decisions. Consequently, counterproductive dam and resource management decisions may be made. This project seeks to address these information needs and reduce the potential for negative or counterproductive management actions.

Information Needs Addressed

The primary information needs addressed by this project are:

> **RIN 2.1.4.** What habitats enhance recruitment of native fish in the LCR and mainstem? What are the physical and biological characteristics of those habitats?
>
> **RIN 2.2.5.** What are the appropriate habitat conditions for HBC spawning? Where are these found? Can they be created in the mainstem?

This project addresses these RINs by investigating what available data indicate are habitat characteristics that support native fish spawning and recruitment and where the data indicate these habitats are found. Improved definition of habitat characteristics that support native fish spawning and recruitment allows for investigation into what would be required to create such habitats.

General Methods

M.E. Andersen, GCMRC Supervisory Biologist, will pursue this project with input from other internal and external scientists. He will attempt to bring in all available data regarding HBC habitat preferences, and those of other native fishes, as available. Considerable effort is anticipated to bring together disparate data sources into a single format that can be subjected to statistical analysis. The multivariate statistical package CANOCO, Version 4.5, and some supporting literature, has been purchased by GCMRC for this purpose. Andersen acquired additional training in multivariate methods in FY 07 in support of this project.

Products/Reports

A brief annual report describing project progress will be produced by September 2007. A more comprehensive 2-year report, describing project progress, needs, and recommendations, will be produced by September 2008. At this time it is anticipated that this project will lead to preparation of at least one manuscript that will be submitted for consideration for publication.

Budget

In FY08, this project will be pursued by M.E. Andersen whose salary is accounted for separately. The cost requests for these years are to allow for staff time and advanced training in statistical methods, some of which may involve travel. All the software and supporting documentation that is necessary to begin this work has already been purchased by the GCMRC.

BIO 2.R11.08	
Native Fishes Habitat Data Analysis (FY07–FY10)	
	Fiscal Year 2008

BIO 2.R12.08: Trammel Net Effects

BIO 2.R13.08: Remote PIT Tag Reading

BIO 2.R14.08: Test Sonic Tags

Start Date

October 2006

End Date

September 2009

Principal Investigator(s)

Led by GCMRC (M.E. Andersen, L.G. Coggins) with assistance from the Arizona Game and Fish Department (AZGFD) and U.S. Fish and Wildlife Service (FWS)

Geographic Scope

The mainstem Colorado River in Grand Canyon

Project Goals/Tasks

The objective addressed by these projects is:

- Determine and refine the most appropriate method(s) for estimating the population size of humpback chub and other Grand Canyon fishes, including sampling design, gear selection, and development of remote monitoring methods. The method(s) developed and selected should be consistent with the second edition of the Colorado River Endangered Fishes Recovery Goals. (The U.S. Fish and Wildlife Service has scheduled revision of the Goals to be initiated in 2007.)

The specific goal of the tasks identified in this project description is to provide evaluations of currently used and potential monitoring techniques. In 2007 and 2008, a study will be conducted to investigate potential improvements in the use of trammel nets, one of the most common gear types in the Colorado River system, but also a gear type that has been implicated in causing stress to fish, a factor of particular importance when handling endangered fishes. This study should also provide quantification of the percentage of native fish populations sampled by trammel nets, an important metric to quantify in order to allow trammel net capture data to contribute to stock assessments. This project also proposes to test two types of monitoring that do not require repeated handling of fishes: 1) remote antennae that can read the PIT tags already implanted in a large fraction of the adult the Grand Canyon HBC population, and 2) sonic tags that once implanted in fish can be read by stationary readers

Need for Project

A limited number of HBC and other native fishes are present in the modern day Colorado River in Grand Canyon. Nonnative fish species are also present, and are important to study because of their potential to prey on and/or compete with native fishes. Scientists and managers wish to know how many of these species are present and the age class structures of these populations. Because of the limited numbers, however, scientists and managers wish to know just how effective their gear is in sampling populations; they also wish to obtain population information in the least intrusive manner(s) possible, especially when sampling the endangered HBC. Although more gear types remain to be tested, the four studies described herein begin to investigate gear efficiencies and potentially useful new gear types.

Strategic Science Questions

The primary science question addressed by this project is:

> **SSQ 1-8.** How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling?

Links/Relationships to Other Projects

Just which mainstem habitats are most important for native fishes is still a matter of debate among scientists and managers who study the Colorado River in Grand Canyon. The river is deep, wide, and swift in Grand Canyon, making fish sampling challenging. Remote sensing techniques may provide increased documentation of fish habitat use. This will be especially useful if it turns out that fishes spend a measurable proportion of their time in habitats not susceptible to traditional gear types, such as nets and electroshocking. With increasing knowledge and quantification of fish habitat preferences, scientists and managers can make increasingly specific recommendations for dam releases that favor creation and maintenance of specific riverine habitat types.

Information Needs Addressed

Trammel Net

> **RIN 2.2.12.** What are the impacts of research activities on mortality, recruitment, and the population size of humpback chub?

Trammel nets can be utilized to track the relative abundance of native and nonnative fishes in the Colorado River. If the nets are used in this way they should be deployed so as to be most effective and as safe as possible.

Remote PIT Tag Reading and Sonic Tags

> **RIN 2.6.5.** How are movement patterns for flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem affected by age, natal stream, and dam operations?

> **CMIN 2.4.1.** Determine and track the abundance and distribution of nonnative predatory fish species in the Colorado River ecosystem and their impacts on native fish.

CMIN 2.6.1. Determine and track the abundance and distribution of flannelmouth sucker, bluehead sucker, and speckled dace populations in the Colorado River ecosystem.

General Methods

Beginning in 2007 a graduate student will be partially supported by GCDAMP funds to pursue study of trammel nets. The student will work with faculty at Northern Arizona University (NAU) led by Dr. Alice Gibb. Initial studies will be conducted at an AZGFD hatchery in large roll-off bins with aquaculture-grade liners used to hold water and fish. The expected study animals will be closely related *Gila* species, probably roundtail chub or bonytail.

Experimentation with the use of remote antennae to read PIT tags will be conducted mainly by personnel from the AZGFD. The study area will focus, at least initially, on the Little Colorado River.

Experimentation with sonic tags will be led by GCMRC and FWS personnel, working closely with the product manufacturer, who is based in Tucson. Initial efforts will focus on capturing nonnative fish that will be implanted with these tags and released to see if the equipment is effective in the large Colorado River.

Products/Reports

The preliminary results of the trammel net study are expected by the summer of 2008, and a completed Master's thesis on the topic should be completed by the summer of 2009.

Annual reports, including results and recommendations, will be provided on the use of the three remote sensing techniques by September 30th of each year. These reports will be used to evaluate whether additional studies are warranted or whether one or more techniques should be abandoned.

Budget

BIO 2.R12.08	
Trammel Net Effects (FY07–FY09)	
	Fiscal Year 2008

BIO 2.R13.08	
Remote PIT Tag Reading (FY07–FY09)	
	Fiscal Year 2008

BIO 2.R14.08	
Test Sonic Tags (FY07–FY09)	
	Fiscal Year 2008

GCDAMP Goal 4. Maintain a naturally reproducing population of rainbow trout above the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish.

BIO.4.M1.08: Status and Trends of Lees Ferry Trout

Start Date

Ongoing

End Date

Ongoing

Principal Investigator(s)

Arizona Game and Fish Department (AZGFD), Ecometric, Inc., and GCMRC

Geographic Scope

Colorado River from Glen Canyon Dam (GCD) to Lees Ferry

Project Goals/Tasks

The objective addressed by this project is:

- Monitor the rainbow trout population below Glen Canyon Dam to monitor responses to various flows

Operation of GCD affects the ecology of nonnative rainbow trout and the aquatic food base in the Lees Ferry reach (McKinney and others, 1999). The Lees Ferry fishery was recognized as a resource of concern in the Operation of Glen Canyon Dam Final Environmental Impact Statement (FEIS) (1995): “NPS, AZGFD, Hualapai, and Navajo objectives for the trout fishery are to provide a recreational resource while maintaining and recovering native fish in Grand Canyon. In the Glen Canyon reach, their objective is to encourage natural reproduction, survival, and growth of trout to blue ribbon quality sizes.” This project is designed to monitor the status of the trout fishery to contribute to evaluation of whether this goal from the EIS is being met. Information needs still exist to understand how the trout population, especially regarding reproduction and survival and growth of young fish, responds to modified low fluctuating flow (MLFF) alternative. An additional task has been added to address this need. These protocols will potentially be modified considering the recommendations of the 2007 PEP.

Need for Project

The downstream fish community is an assemblage of native and nonnative fish that occur in the Colorado River ecosystem. The status and trends of the fishery are regulated by biotic and abiotic mechanisms that may in turn be affected by the operations of GCD. Monitoring basic population statistics including abundance and distribution of native and nonnative fishes provide information necessary to assess the status of these resources and inform the Adaptive Management Program.

The AZGFD has worked with other fishery cooperators including the GCMRC, FWS, and SWCA Environmental Consultants over the past 5 years to develop consistent, repeatable sampling methods for fishes in both the mainstem Colorado River and LCR. The overall objective of this proposal is to continue standardized sampling and continue to work to develop a long-term monitoring program for all fish populations. The Department will also assist with other special projects and research needs as appropriate.

Strategic Science Questions

The primary science question addressed by these projects is:

> **SSQ 3-6.** What GCD operations (ramping rates, daily flow range, etc.) maximize trout fishing opportunities and catchability?

Links/Relationships to Other Projects

Understanding the status of the Lees Ferry rainbow trout population is critical to estimating and monitoring the risk that this species may pose to native fishes both in the Lees Ferry reach and further downstream. Following implementation of a 4-year project to remove rainbow trout from the LCR reach of the Colorado River, it will be critical to understand the status and trends of Lees Ferry rainbow trout to help evaluate any re-population of downstream reaches that may occur.

Information Needs Addressed

The primary information needs addressed by these projects are:

> **CMIN 4.1.2.** Determine annual proportional stock density of rainbow trout in the Lees Ferry reach.
>
> **CMIN 4.1.4.** Determine annual standard condition (Kn) and relative weight of rainbow trout in the Lees Ferry reach.

There are a number of RINs that are partially addressed by this project, or which depend, in part, on the results of this project. The primary RIN addressed is:

> **RIN 4.1.1.** What is the target proportional stock density (i.e., trade-off between numbers and size) for rainbow trout in the Lees Ferry reach?

The data collected with the monitoring in this project provide the data on which managers depend to monitor the size and condition of the current rainbow trout population.

General Methods

The fishery is sampled by electrofishing to estimate biological parameters to assess the status and trends of the fishery. Electrofishing provides information on size composition, relative abundance (catch per minute as an index of population size), condition (length weight relationships), and samples are collected for whirling disease examination. Samples are collected at 27 stratified random and 9 fixed electrofishing transects 3 times per year in an augmented, serially alternating sampling design as recommended by the PEP panel. Present sampling design can detect a 6–10% linear change in abundance over a 5-year period. Work is currently underway to assess the statistical power of intra- and inter-annual comparisons. We are evaluating other methods to estimate abundance, including snorkel surveys (Korman and others); mark-recapture population estimates similar to those done in 1991 and 1998; and depletion sampling to convert CPUE estimates to population estimates.

Present methods for assessing abundance using a catch rate index may or may not be adequate for addressing management objectives and targets. If managers need an "n" (number of fish), further work needs to be done to find the most cost effective way to generate reliable population estimates. We are working to evaluate different abundance estimators and discussing management targets with managers (AZGFD) and anglers. We will likely suggest some alternative methods to assess the abundance objective rather than "annual population estimates" as stated in CMIN 4.1, or attempt to clarify the CMIN.

Ongoing analysis of and sampling for trout redds and young-of-year trout will be conducted. The scope of work for this project is being negotiated and finalized.

Products/Reports

Separate reports will be provided for the mainstem sampling on or before January 1 of the year following the sampling for internal and external review. The revised final deliverable will be submitted on or before March 31 of the year following the sampling.

Budget

BIO 4.M1.08	
Status & Trends of Lees Ferry Trout (FY07–FY11)	
	Fiscal Year 2008

BIO 4.E1.08: Monitoring Rainbow Trout Redds and Larvae

Start date

October 1, 2007

End date

September 30, 2008

Principal Investigator

Joshua Korman, Ecometric, Inc.

Geographic Scope

The Lees Ferry reach of the Colorado River

Project Goals and Tasks

1. Monitor the responses of rainbow trout redds and larvae in the Lees Ferry reach to dam release patterns

2. Complete model development and testing;

3. Document extent of biases and precision of model parameters under a range of sampling strategies (e.g., how many redd and fry surveys are required);

4. Analyze the 2003-2007 data within this modeling framework to provide the most reliable estimates of the effects of the 2003/2005 experimental flows and other non-experimental impacts (e.g., 2004 flood, Sept. 1 minimum flow reduction);

Need for Project

Increased flow fluctuations are thought to affect rainbow trout abundance through two mechanisms. Variation in river stage would lead to exposure and temporary desiccation of redds which in turn could lead to a reduction in egg and alevin survival rates. A number of studies have shown that egg stages are relatively insensitive to short-term desiccation events but that eleutheroembryos and pre-emergent alevins are very sensitive to desiccation (e.g., Becker et al. 1982). Variation in river stage would also destabilize shoreline habitats forcing fry and parr to move from protective shoreline cover and increase their predation risks and energetic costs, ultimately leading to reduced survival and growth. McKinney et al. (2001) hypothesized that this was the most likely mechanism explaining the increase in the abundance of small rainbow trout observed following reduced flow fluctuations from Glen Canyon Dam (GCD).

In theory, monitoring the abundance of adults would provide an assessment of the effects of increased flow fluctuations on rainbow trout populations in Glen or Grand Canyons. In practice, this approach is complicated by a number of factors: 1) it may be institutionally difficult to implement a sound experimental design where the treatment is held constant for sufficient time for its effects to become observable in the adult population that is

monitored. Recruitment pulses generated from single-year experiments may be swamped by the presence of multiple year-classes in the adult population; and 2) there will be a considerable lag (3+ yrs) between the time that recruitment of juvenile trout is changed and the time it takes for this change to be potentially noticeable in the adult population if a long-term experiment is implemented.

Considering these challenges, it is reasonable to investigate other monitoring alternatives that are more amenable to detecting the effects of short-term (i.e., single- or two-year) experiments with minimal lag time. Korman et al. (2005) documented the utility of estimating survival rates of incubating life stages and young-of-year (YoY) rainbow trout to assess the effects of experimental fluctuating flows in 2003 and 2004. The methodology appears to have considerable promise to estimate key biological parameters (survival, growth, habitat use, movement) that determine the strength of the age-1 year class that ultimately determines the size of the adult population. The study continued in 2006 at a reduced level of funding. 2006 was the first non-treatment year when ROD flows were implemented throughout the spawning and incubation period. 2006 therefore represents a control period that can be used to compare incubation and fry survival rates under Record of Decision conditions with those experienced under experimental flows. Data from the 2006 surveys proved very useful to managers in documenting at least a 90% decline in spawning intensity in the winter of 2006. In spite of the large decline in spawning activity, the July 2006 fry survey results suggested that densities are ½ to ¾ of the levels in 2004. These data suggest that there is a strong compensatory survival response of young trout. This observation is of interest to managers both for assessing the efficacy of reducing trout abundance by focusing on incubation stages, as well as whether to stock fry due to the recent downturn in abundance.

Strategic Science Questions

This project addresses the following Strategic Science Question

SSQ 1.1. Does a decrease in the abundance of rainbow trout and other cold and warm water nonnatives in Marble and eastern Grand canyons result in an improvement in the recruitment rate of juvenile humpback chub to the adult population?

Assuming that at least some of the rainbow trout observed in the Little Colorado River reach are produced in the Lees Ferry reach, understanding the cohort success of the Lees Ferry rainbow trout will be important to correlate with humpback chub population dynamics.

Links to Other Projects

Because rainbow trout were hypothesized to have negative impacts on the native fish population, the Adaptive Management Program implemented an experimental nonnative fishes removal project from 2003 through 2006. The primary species removed was rainbow trout, although smaller numbers of other nonnative fish species were also removed. Although the source of the rainbow trout removed has not been determined with certainty, there is evidence that the fish migrated downstream from the Lees Ferry reach. If rainbow trout do have negative impacts on native fishes and these rainbow trout are migrating from the Lees Ferry reach, then the condition of the Lees Ferry rainbow trout population is of great importance to managers as they determine actions to take that benefit the native fish population in Grand Canyon.

Information Needs Addressed

RIN 4.1.1. What is the target proportional stock density (i.e., trade-off between numbers and size) for rainbow trout in the Lees Ferry reach?

RIN 4.1.2. What is the minimum quantity and quality of spawning substrate necessary for maintaining a wild reproducing rainbow trout population in the Lees Ferry reach?

EIN 4.1.1. How does rainbow trout abundance, proportional stock density, length at age, condition, spawning habitat, natural recruitment, whirling disease and other parasitic infections change in response to an experiment performed under the Record of Decision, unanticipated evern, or other management action?

General Methods:

Incubation Mortality Model

We have developed a model that integrates the effects of spawn timing, redd hypsometry (proportion of redds by elevation band), and the effects of intergravel water temperature on incubation time and mortality, to predict the relative incubation mortality for daily spawning cohorts. The model consists of five components:

1. ***Spawn Timing.*** The spawn timing model is used to predict the number of redds created by day over a one year period (November 1 – October 31);

2. ***Redd Hypsometry.*** Redds created on each model day are distributed across four elevation bands (<5, 5-8, 8-12, 12-15, and 15-20 kcfs) based on the observed hypsometry;

3. ***Incubation Time.*** The number of days from spawning to hatch are computed based on the time required to exceed an Accumulated Thermal Unit (ATU) threshold of 329 degree (^{o}C)-days (Jensen et al. 1992) using daily average intergravel temperature measurements. Incubation time varies for each spawning day and elevation band because of differences in temperature histories. The number of days between hatching and emergence was fixed at 30 days that was determined from the otolith microstructure of a large sample of age-0 rainbow.

4. ***Temperature-Dependent Incubation Mortality.*** Daily maximum and minimum intergravel water temperatures over the incubation period are compared to temperature-mortality thresholds. If the daily maximum or minimum temperatures over the incubation period exceed assumed lethal thresholds, redds created on that day are recorded as not producing viable young.

5. ***Predict Hatch Timing.*** The numbers of both viable and total redds are summed across elevation bands for each spawning day. The ratio of the number of non-viable redds to the total number of redds provides a prediction of the daily relative incubation mortality rate. Predictions are shifted from spawning date to hatch date based on the computed incubation time for each spawning date and elevation band.

The predicted hatch date distribution based on the combined spawn timing and incubation mortality models, hereafter referred to as incubation mortality-based predictions, represents the distribution that would result

assuming temporal and spatial variation in incubation mortality determined by dewatering frequency. The predicted hatch date distribution based on the spawn timing model alone, hereafter referred to as spawn timing-based predictions, represents the distribution that would result assuming constant incubation mortality. This latter prediction represents the null model as it assumes that mortality is not dependent on dewatering frequency determined by the flow regime.

This model will be applied using count, hypsometry, and temperature data aggregated over the entire Lee's Ferry reach. Maximum and minimum daily temperatures thresholds during the egg (spawn-to-hatch) and alevin (hatch-emergence) incubation periods were derived from the literature.

Products/Reports

a. Document data, model, and results from 2003-2007 (four study years) in four manuscripts to be submitted to peer-reviewed journals by June 2008;

b. Provide two brief management reports covering:
    i. Data/methods not described in sufficient detail in the peer-reviewed manuscripts;
    ii. Results from the sampling strategy analysis.

c. Present findings at one TWG or AMWG meeting at the end of the project and to the trout PEP panel.

Budget

BIO 4.E1.08	
Monitoring Rainbow Trout Redds & Larvae (FY08)	
	Fiscal Year 2008

GCDAMP Goal 5: Maintain or attain viable populations of Kanab ambersnail.

BIO 5.R1.08: Monitor Kanab ambersnail (Includes backwater monitoring of small-bodied fishes)

Start Date

April 2007

End Date

September 2010

Principal Investigator(s)

GCMRC (B.E. Ralston) and Arizona Game and Fish Department

Geographic Scope

Vasey's Paradise is located 31.5 river miles downstream of Lees Ferry. Surveys encompass the springs around the pour-off at Vasey's Paradise.

The monitoring of Kanab ambersnail is conducted in conjunction with monitoring of backwater habitats for small-bodied fishes.

Project Goals/Tasks

The goals of this project are to determine extent and kind of vegetation that exists as habitat for the Kanab ambersnail (KAS) and to track the abundance and distribution of KAS at Vasey's Paradise. The following is a list of tasks required to meet these goals:

1. Sample vegetation plots at Vasey's Paradise to determine patch composition and areal extent (spring and fall of each year). Sample for the presence of snails in plots.

2. Enter data and conduct quality control on data entry. Provide data to GCMRC for vegetation analysis.

3. Compare previous vegetation composition to previous vegetation/habitat surveys to assess habitat. Provide abundance estimates of snails. Report writing by GCMRC (winter of each year).

4. Provide snail density estimates based on sampling or model estimates.

Need for Project

Knowing the extent of habitat is needed in the event of a high flow to support development of a biological opinion and to help determine snail densities. Changes in snail numbers can be associated with changes in vegetation. By monitoring the vegetation at Vasey's Paradise, the snails are indirectly monitored, based on the assumption that if the preferred habitat is present then snails will also be present. Total habitat can be measured using remote methods, but the composition of the habitat may still require on the ground sampling. Sampling at Vasey's Paradise can also provide data for GCDAMP goal 6, which refers to the protection and improvement of riparian and spring communities.

Strategic Science Questions

There are no strategic science questions that are directly related to the goal of maintaining or attaining viable populations of Kanab ambersnails. The specific information needs addressed by the project are indicated below.

Links/Relationships to Other Projects

Riparian vegetation, including vegetation at springs, is a critical interface between aquatic and terrestrial environments around the world. There are multiple components that riparian and spring communities either contribute to or influence (e.g., food base, available habitat). In the CRE, the spring vegetation itself serves as a host for invertebrates, like Kanab ambersnail, provides breeding and foraging habitat for small mammals and birds, provides cover in the heat of the day, and the spring water may be used for ceremonial purposes. Changes in the composition or structure of riparian spring communities like expansion of an exotic species may alter these interactions. Riparian and spring vegetation regulates nutrient exchange between the land and water, and leaf litter is a terrestrial carbon source that may influence in-stream invertebrate production. The relative importance of terrestrial carbon in the aquatic food web is, in part, being addressed through the food base initiative. The linkage could be further defined through studies that focused on terrestrial productivity and processes. Again, changes in abundance or kind of riparian carbon sources may influence aquatic and terrestrial productivity processes.

Information Needs Addressed

These following CMINs will be directly addressed by this project:

> **CMIN 5.1.1.** Determine the abundance and distribution of Kanab ambersnails at Vasey's Paradise in the lower (below 100,000 cfs) and upper zone (above 100,000 cfs).
>
> **CMIN 5.2.1.** Determine and track the size and composition of habitat used by Kanab ambersnail at Vasey's Paradise.

General Methods

Habitat Sampling

- Determine percent cover, diversity, and distribution of vegetation that constitutes KAS habitat. Random samples in the habitat record percent cover, plant height of dominant plants, and soil

moisture. Survey total habitat and plots using conventional or alternative survey methods. Habitat area is calculated by GCMRC survey department. Data are analyzed using univariate and multivariate approaches. A minimum of 10 samples will be taken for each patch, if possible.

- Snails will be sampled in each patch. Number of snails encountered and the size of snail recorded.
- Data are entered and quality checked. Data are delivered to GCMRC for analysis.
- Evaluate current habitat parameters to historic data for comparison.
- Monitor relocated vegetation associated with high flow experimental conservation measures.

Products/Reports

An annual report for KAS habitat and density estimates is produced by Arizona Game and Fish Department. An annual report of the results of backwater seining for small-bodied fishes is produced by GCMRC.

Budget

BIO 5.R1.08	
Monitor Kanab Ambersnail (FY95–FY10)	
	Fiscal Year 2008

GCDAMP Goal 6: Protect or improve the biotic riparian and spring communities, including threatened and endangered species and their critical habitat.

BIO 6.R1.08: Vegetation Mapping

BIO 6.R2.08: Vegetation Transects

Start Date

October 2006

End Date

September 2010

Principal Investigator(s)

GCMRC (B.E. Ralston) and other cooperators (e.g., USGS, Northern Arizona University) to be determined

Geographic Scope

The riparian zone, including the old high-water zone (>97k cfs), in the Colorado River corridor from Glen Canyon Dam (GCD) to Lake Mead

Project Goals/Tasks

The goals of these projects are to determine the areal extent of vegetation classes among the major habitats zones in the Colorado River ecosystem (CRE) (e.g., new high-water zone, sand beach community, old high-water zone) and how yearly GCD operations effect vegetation cover, richness, diversity, and wetland indicator value by surface elevation. The following tasks are designed to reach these goals:

1. Conduct field surveys to identify community constituents and determine if vegetation overstory species and cover values have changed. Use community analysis—ordination, two-way species analysis—to identify how understory communities may be changing. (September-Oct 2007) *Pending PEP recommendations*

2. Use image processing software (e.g., ENVI, ERDAS) to classify imagery into identified vegetation classes (fall/winter 2008). Imagery is from 2009 overflight and compared with the 2002 imagery for the purposes of change detection.

3. Ground-truth accuracy of vegetation classification (September 2008)

4. Compare revised vegetation map to previous vegetation map to determine area change for vegetation classes. Report writing. (Fall 2008).

5. Conduct field surveys of vegetation transects perpendicular to the river at specific stage elevations (15, 25, 35, 45, and 60 kcfs) Fall 2008. *Pending PEP recommendations.*

6. Data analysis – data entry and quality control assessment, analysis for diversity, cover, richness and wetland score across elevations. Community analysis for marsh plots. Compare with previous years to assess trends (Winter 2008).

7. Reporting results – incorporate into a yearly report and into SCORE reporting (winter/spring 2008 and each subsequent year).

Need for Project

Riparian vegetation expansion, since operations at Glen Canyon Dam began in 1963, has had a pivotal role in the ecology of the postdam river corridor. The reduction in annual flood volumes has allowed vegetation to expand and more permanently occupy land previously subjected to scouring in most years. The expansion has included marsh habitat occurring throughout the Colorado River ecosystem (CRE), whereas previously, these habitats were restricted to Glen Canyon and the western Grand Canyon (Clover and Jotter, 1944; Turner and Karpiscak, 1980). The plants associated with the expansion include alien species like salt cedar (*Tamarix ramossisma*), camel thorn (*Alhagi maurorum*), and peppergrass (*Lepidium latifolium*), but also native species, arrowweed (*Pluchea sericea*), seepwillow (*Baccharis emoryi*), and coyote willow (*Salix exigua*). The variable operations over the years have resulted in an ebb and flow of vegetation expansion with vegetated area generally increasing over time (Waring 1995; Ralston and others, *in prep*). The increase in terrestrial vegetation contributes to above ground primary productivity, arthropod densities and associated food resources for terrestrial and aquatic vertebrates, is a source of culturally important plant species and also can cause conflicts with recreational activities like available camping area. Because riparian vegetation is linked to multiple resources, knowing how vegetation is changing via monitoring (e.g., which species are expanding or declining and where) is an important source of data when evaluating dam operations.

To address the AMWG needs associated with riparian vegetation requires system-wide assessment of vegetation change at the broad scale (new high-water zone) as well as at the local scale (plot data). While knowing how much vegetation in the river corridor exists is useful, it is equally useful to know how the species that make up the vegetation may be changing. Because riparian vegetation contributes to aquatic productivity (Naiman and others, 2005) and serves as a host to terrestrial invertebrates and higher order vertebrates (e.g., lizards, birds), assessing the quality of these plants can help explain changes observed in higher order vertebrate abundances, including fish species (Nakano and Murakami, 2001). Changes in riparian vegetation are associated with dam operations (Stevens and others, 1995; Kearsley, 2004) and can affect the propagation of exotic species like tamarisk (Porter, 2002). Yearly transects assess year-to-year operations that can detect changes among herbaceous species, including invasives, while remotely sensed data can assess changes in overstory wood species that change more slowly.

The three riparian vegetation studies proposed in the annual work plan are composed of two field-based studies (1. Vegetation dynamics; 2. Vegetation mapping that utilizes corridor-wide overflight data scheduled in 2009)

and an office based study (3. Riparian vegetation synthesis Part I). The two field-based projects compliment each other rather than replicate efforts. Vegetation dynamics is an annual monitoring effort that records species diversity, richness and cover at specific stage elevations. The changes in vegetation parameters that this monitoring detects is relevant to perennial and annual herbaceous species like bunch grasses, marsh species and invasive species that can change on an annual basis. Vegetation mapping utilizes the digital overflight imagery (product of Data Acquisition, Storage, and Analysis (DASA) Program) to quantify larger scale area changes (e.g., expansion of arrowweed patches, or extent and type of vegetated shoreline). Imagery is from 2009 overflight and compared with the 2002 imagery for the purposes of change detection.Analysis of change detection in the vegetation mapping project would incorporate the annual transect survey results to help explain patterns of change that may occur over a 5-year time frame. The two projects compliment each other because they provide information about changes in riparian habitat at different ecological scales which may affect other riparian community constituents like invertebrate biomass and riparian bird abundances. Lastly, the vegetation synthesis would use results from both of these studies and previous mapping and monitoring results to test mechanisms that affect riparian vegetation establishment and expansion including rates of change potential colonization sites.

Strategic Science Questions

The primary strategic science questions addressed by these projects are:

> **SSQ 2-1.** Do dam controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?
>
> **SSQ 4-2.** How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs (displacement and possible mortality of young humpback chub) associated with high flows?
>
> **SSQ 5-7.** How do warmer releases affect viability and productivity of native/nonnative vegetation?

GCDAMP goal 6 is directed at the protection or improvement of riparian and spring communities. This goal is based on the recognition that the riparian and spring environments are hosts for some endangered species like the southwestern willow flycatcher (*Empidonax traillii extimus*). The protection of these species' critical habitats is part of this goal. Riparian plant communities can be viewed at either a single resource level without ecosystem linkages, or at a integrative level where riparian vegetation is linked to aquatic and terrestrial ecosystem processes (e.g., contributes to secondary production, cover), interacts with cultural resources associated with recreation (e.g., camping sites) and traditional cultural properties, or affect aeolian sand transport and possibly archaeological site erosion rates. Understanding how riparian vegetation responds to flows and affects other resources of concern forms a basis for managing critical resources like native fish, archaeological properties, and recreational components.

Links/Relationships to Other Projects

Riparian vegetation is a critical interface between aquatic and terrestrial environments around the world. In the CRE, the vegetation itself serves as a host for invertebrates, provides breeding and foraging habitat for birds, provides cover in the heat of the day, and may be harvested for cultural utility. Changes in the composition or structure of riparian vegetation like expansion of an exotic species may alter these interactions. Riparian vegetation regulates nutrient exchange between the land and water, and leaf litter is a terrestrial carbon source that may influence in-stream invertebrate production. The relative importance of terrestrial carbon in the aquatic food web is, in part, being addressed through the food base initiative. The linkage could be further defined through studies that focus on terrestrial productivity and processes. Again, changes in abundance or kind of

riparian carbon sources may influence aquatic productivity processes. The 2005 Knowledge Assessment Workshop revealed that there was some certainty about the relationship of marsh community development and flows for the CRE, but that this certainty decreased as one progresses upslope. The outcome of the Knowledge Assessment Workshop and the science questions for riparian habitats indicate that, besides knowing the influence of flow on composition and extent of riparian vegetation, an understanding of the integrated role of riparian vegetation with other resources is needed (e.g., aquatic or cultural resources). This understanding would come from a combination of monitoring, synthesis, and field research.

Information Needs Addressed

Parameters and metrics to be measured, and the CMINs that each element addresses.

Determine and track the status and trends of the identified riparian communities (e.g., marsh community, sand beach, nonnative invasive species, etc.) at the appropriate time scale (CMIN 6.1.1, 6.2.1, 6.5.1. 6.6.1). This need will be addressed through:

1. Semi-decadal CIR digital imagery mapping would quantify:
    - Area change of dominant overstory species
    - Ground-truth associated with mapping would quantify community composition and possibly identify changes in understory community composition.
    - Provide coarse primary productivity estimates for riparian vegetation.
2. Annual vegetation transects/grid surveys that correlate with river stage elevations of 15, 25, 35, 45, and 60k cfs). Quantifies cover, richness, and diversity and wetland species scores at each stage elevation. This work would be most informative for herbaceous annuals and perennials, including invasive species. This component would need to incorporate marsh monitoring needs of tribes.

General Methods

Vegetation Mapping

1. Community identification will be done using releve′ plots in the field that are used to record relative cover. Cover scales use a Daubenmire scale. Data are recorded as categorical data, but plant height of the dominant species is also recorded. Number of samples for each plot is dependent on the abundance of the vegetation type. A minimum of 10 samples will be taken for each community (6 types identified in 2002). These data will be analyzed using multivariate statistics (ordination techniques) to identify the dominant communities along the river corridor.
2. Vegetation classification will use supervised classification routines that are available in an image processing software package (ENVI, 2005). Training areas will be selected from previous base map ground-truth. Classes that will likely be used for this effort include tamarisk, baccharis/salix, marsh/wetlands, mesquite/acacia, arrow weed and bare ground. User and producer accuracies will be determined and class aggregation may be required to meet national vegetation mapping standards. The scheduled 2009 overflight would be compared with 2005 and 2002 imagery for vegetation area change detection purposes.

3. Quantification of changes in riparian communities will be done using a Geographic Information Systems (GIS) platform (ArcMap, ESRI, Inc. 2002).

Vegetation Transects

1. Data collection involves recording vegetation cover of species within each of four ($1m^2$) plots at each elevation. Transects are located throughout the river corridor and sampled in a rotated panel design so that some plots are sampled every year (n=20) and others are sampled every 3 years (n=40). Marsh data will be incorporated for tribal monitoring (August/September 2008 and each year following, pending PEP recommendations).

2. Sample locations are determined by using the STARS model of Randle and Pemberton (1987) which predicts elevation rise based on river stage in combination with the Colorado River flow, and Sediment Storage/Graphic User Interface (CRFSSGUI) model (Korman and Walters, 1998) which uses STARS model data and information on channel gradient, width, and roughness to predict the timing and height of the hydrograph at any point along the river

3. Vegetation Sampling. Sampling of each transect correspond to five stage elevations (15, 25, 35, 45, and 60 kcfs). At each elevation point, a 1 x 1m sighting frame (per Floyd and Anderson, 1982) with 100 crosshair intersections is placed and leveled with one side along the transect and the riverward corner of the transect side directly over the pin flag. Once a frame was surveyed, the frame is moved upstream or downstream at the same level so that four 1 x 1m areas are sampled (two frames upstream of the transect and two downstream).

4. Vegetation data are recorded in the following way. First, all species present in the 1 x 1m areas are recorded. These data are included in the univariate measures (cover, richness, diversity), but are excluded from the multivariate analyses.

5. To estimate percent vegetative cover in each frame, the number of sighting points which intercepted each species is counted. If multiple species were present under a single sighting point, all are recorded once so that the total cover of all species can collectively sum to more than 100%. Species which are encountered in at least one of the frames, but which are not seen beneath any of the 400 sighting points, are assigned an arbitrary "trace" cover value of 0.001%.

Products/Reports

Annual report for vegetation transect monitoring and a single 5-year report for vegetation mapping change detection. An annual progress reports will be provided for mapping/change detection project. Peer-reviewed articles from vegetation mapping project regarding change detection as well as remote sensing technology and its utility in mapping vegetation in the arid Southwest.

Budget

BIO 6.R1.08	
Vegetation Mapping (FY07–FY10)	
	Fiscal Year 2008

BIO 6.R2.08	
Vegetation Transects (FY07–FY10)	
	Fiscal Year 2008

BIO 6.R3.08: Vegetation Synthesis

Start Date

October 2006

End Date

September 2010

Principal Investigator(s)

GCMRC (B.E. Ralston) and other cooperators to be determined

Geographic Scope

The riparian zone, including the old high-water zone (>97k cfs), in the Colorado River corridor from Glen Canyon Dam (GCD) to Lake Mead

Project Goals/Tasks

To goal of the project is to utilize existing data from the riparian zones to characterize temporal and spatial responses of riparian vegetation to Glen Canyon Dam operations (FY07–FY08). The following tasks are designed to meet the goal of this project:

1. Conduct literature and data review of research associated with GCD and data from other rivers to identify appropriate data sets for synthesis at multiple scales (local, reach, systemwide)

2. Topic discussed per scale (local, reach, etc)

    a. Biomass
    b. Species diversity
    c. Rates of change – community scale
    d. Incorporation of physical resource information.
    e. Determine between site/scale differences
    f. Aquatic and terrestrial linkages - preliminary analysis

3. Report results

4. Utilize local and reach based parameter values to produce a sub-model of riparian vegetation response to changes in operations

5. Identify modeling tool for use (e.g., Stella, GCM)

6. Model development – parameter definitions and model run. Use intermediate disturbance hypothesis (Huston, 1979; Roxburgh and others, 2004) to test changes in parameters and conceptual model of riparian vegetation response to operations in CRE

7. Verification of model using published data

8. Reporting results – incorporate into a yearly report and into SCORE reporting

Incorporate vegetation synthesis results into terrestrial faunal aquatic biology research and cultural program to improve CRE model (FY09–FY10).

Need for Project

GCMRC recognizes that there is a large amount of information in the gray literature associated with riparian vegetation for the Colorado River. The synthesis is intended to utilize the results of these data to construct a synthesis for riparian vegetation. The synthesis would evaluate vegetation change, interactions and ecosystem function at local, geomorphic and systemwide scales. The synthesis will incorporate data from other disciplines, most notably the physical science program, as it has completed a synthesis in 2004 (Schmidt and others, 2004). The synthesis should result in several papers that would be submitted for publication in peer-review journals.

The synthesis would consist of two phases with the first phase representing a summary of information and hypotheses generation from review of the material and incorporation of other studies from other rivers. The second phase would be model development to test hypotheses for riparian vegetation change along the river corridor. The model would contribute to our conceptual model of carbon cycling within the CRE.

The identification of mechanisms of change provides loose predictive capabilities regarding the response of riparian vegetation to operations and the associated response in terrestrial and aquatic fauna that are affected by riparian community structure and composition. The compilation and synthesis of sediment and gage data since 1965 and earlier (Topping and others, 2003; Schmidt and others, 2004) provides a rich data set that forms a basis for study of how discharge and sediment volumes influence community structure within the riparian community.

Strategic Science Questions

The most critical strategic science questions addressed by this project are as follows:

SSQ 2-1. Do dam controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?

SSQ 4-2. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs (displacement and possible mortality of young humpback chub) associated with high flows?

SSQ 5-7. How do warmer releases affect viability and productivity of native/nonnative vegetation?

GDDAMP goal 6 for terrestrial resources is directed at the protection or improvement of riparian and spring communities. Included in the goal is the recognition that the riparian and spring environments are hosts for some endangered species like the southwestern willow flycatcher (*Empidonax traillii extimus*). The protection of these species' critical habitats is part of this goal. Riparian plant communities can be viewed at either a single resource level without ecosystem linkages, or at a integrative level where riparian vegetation is linked to aquatic and

terrestrial ecosystem processes (e.g., contributes to secondary production, cover), interacts with cultural resources associated with recreation (e.g., camping sites) and traditional cultural properties, or affect aeoliean sand transport and possibly archaeological site erosion rates. Understanding how riparian vegetation responds to flows and affects other resources of concern forms a basis for managing critical resources like native fish, archaeological properties, and recreational components.

Links/Relationships to Other Projects

The expansion of vegetation along the river corridor affects multiples resources. The increased shoreline vegetation contributes to aquatic drift and may serve as supplemental source of carbon for aquatic food webs in addition to in-stream production. The ecology of human behaviors along the river corridor is affected by riparian vegetation. Exotic species that spread by tributary introductions (e.g., camel thorn) impact campable area by making some beaches unusable. Available campsite area is dependent on amount of open sand, availability of trees and shrubs for shade and wind breaks, and accessibility to the river (i.e., steepness of bank) among other variables (Kearsley and others, 1994; Kaplinki and others, 2005). In a similar vein, culturally important plants and locations have been monitored under the auspices of the adaptive management program since the 1990s (Phillips and Jackson, 1996; Austin and others, 1997; Lomaomvaya and others, 2001). How these data have change over time also needs to be incorporated into a synthesis to provide a holistic view of the riparian community.

Information Needs Addressed

The primary information needs addressed by these projects are core monitoring information needs (CMINs) 6.1.1., 6.2.1, 6.5.1, and 6.6.1, which are summarized as:

Determine and track the abundance, composition, distribution, and area of terrestrial native and nonnative vegetation species in the Colorado River ecosystem.

Parameters and metrics to be measured, and the information needs that addresses each element.

How has the abundance, composition, and distribution of the OHWZ, NHWZ, sand beach community changed since dam closure (1963), high flows (1984), interim flows (1991), and the implementation of Record of Decision operations (RIN 6.2.1, 6.3.1, 6.4.1, 6.5.1, 6.5.2, 6.5.3)?

1. Vegetation patches from 2002 vegetation base map will be compared with previous vegetation maps (Waring, 1995) that were completed for sections of the river for years 1965, 1973, 1984, 1990, and 1991) to determine distribution and abundance information at a gross scale (e.g., NHW, OHW, sand beach, marsh). Area coverage will be provided for different for zones.

2. Compositional changes are more difficult to determine. Will attempt modeling after assessing local, historic plot data (e.g., Stevens and Ayers, 1993, 1997; Kearsley and Ayers, 1996) and identifying local and reach scale factors that influence community assembly rules. Validation of model using 2005 CIR imagery and ground surveys that coincide with mapping project (FY08).

Change detection between years to identify change in area and distributional changes for woody exotics (e.g., tamarisk).

General Methods

1. Landscape change detection using GIS analysis tools to identify area change for vegetation classes or zones of interest between years. Identification of tamarisk in black and white imagery will be done using 2002 and 2005 imagery and comparing imagery characteristics of the vegetation. The scanning project in DASA is orthorectifying historic imagery that will permit retrospective analysis of vegetation change.

2. Quantification of changes in riparian communities will be done using a GIS platform (ArcMap, ESRI, Inc. 2002).

Vegetation modeling

1. Incorporate parameters

2. Physical parameters (discharge, rates of sediment loss/gain by reach)

3. Precipitation records – decadal

4. Rates of change for vegetation class – obtained from change detection question.

5. Utilize intermediate disturbance hypothesis (Roxbury and others, 2004; Barnes and others, 2006) to test assumptions of species interactions within the CRE.

6. Validate using vegetation transect data and composition data associated with vegetation mapping.

Products/Reports

Semi-annual report of progress. Final report. Individual reports for segments of synthesis submitted for publication.

Budget

BIO 6.R3.08	
Vegetation Synthesis (FY08–FY10)	
	Fiscal Year 2008

GCDAMP Goal 7: Establish water temperature, quality, and flow dynamics to achieve the Adaptive Management Program ecosystem goals.

BIO 7.R1.08: Water Quality Monitoring of Lake Powell and the Glen Canyon Dam Tailwater

Start Date

Ongoing (current Interagency Agreement with the Bureau of Reclamation (Reclamation) in place through 9/30/2009)

End Date

September 2009

Principal Investigator(s)

William S. Vernieu, Hydrologist, GCRMC

Geographic Scope

Lake Powell and its major tributary arms, inflow tributaries entering Lake Powell, and the tailwater from Glen Canyon Dam (GCD) to Lees Ferry.

Project Goals/Tasks

1. Maintain water-quality monitoring program for Lake Powell to predict and track processes in the reservoir that may influence GCD release water quality.

2. Maintain water-quality monitoring in GCD tailwater to directly evaluate the quality of GCD releases, the effects of GCD operations, and suitability for downstream aquatic resources.

3. Develop, in conjunction with Reclamation, CE-QUAL-W2 model to predict future changes to the water quality of Lake Powell and GCD releases, simulate the effects of various proposed and hypothetical climate, experimental and operational scenarios, and guide future monitoring program revisions.

4. Complete comprehensive database of water-quality information from 40-year monitoring program and publish results as USGS Data Report for further interpretation, synthesis, and analysis

5. Revise monitoring program, as needed, in conjunction with development of CE-QUAL-W2 model and historical data analysis, to ensure most efficient means of maintaining cost-effective and reliable monitoring program

Need for Project

Processes within Lake Powell, climate changes in the upper Colorado River Basin, the structure of GCD, and various aspects of dam operation affect the quality of water released from GCD to the Colorado Rover ecosystem (CRE) in Grand Canyon. Temperature, dissolved oxygen concentrations, nutrient concentrations, biological composition, and other characteristics of GCD releases can have a profound effect on the aquatic ecosystem below the dam.

The 5-year period of below-normal inflows in the upper Colorado River Basin from 2000 to 2004 resulted in a drawdown of Lake Powell of over 140 ft to 3,555 ft, representing 38% of total capacity, in 2005. Increasing influence of Lake Powell surface layers on GCD releases can be expected to cause warmer release temperatures, decreased release nutrient concentrations, and increased export of aquatic biota from Lake Powell. The lowering of warm surface layers in relation to the penstock withdrawal elevation has resulted in above-normal late-summer release temperatures since 2003. Release temperatures of 16°C were recorded in October 2005, representing the warmest releases since 1971. Resuspension of exposed deltaic sediments from reservoir drawdown by 2005 inflow currents resulted in a plume of hypoxic water that appeared at GCD and began to be incorporated in GCD releases in July 2005. This resulted in dam releases containing the lowest concentrations of dissolved oxygen on record, reaching 3.3 mg/L in October 2005. Changes to individual turbine operations at GCD in September and October 2005 were shown to have a significant effect on the reaeration of hypoxic releases.

Differential routing of winter inflow currents can cause longer-term changes to the water quality of Lake Powell and eventual dam releases. For the past 7 years, with the exception of 2006, winter *underflow* density currents moved along the bottom of the reservoir and refreshed oxygen concentrations in the deepest layers of Lake Powell. In contrast, from 1994 to 1999 and during other periods in Lake Powell's history, winter density currents moved through the reservoir in intermediate layers as an *interflow*, which caused stagnation and a reduction of dissolved oxygen concentrations in the deepest hypolimnetic water of the reservoir. This interflow pattern again appeared in 2006. Exceptionally cold winter inflows in caused an underflow in January 2007, increasing hypolimnetic density and increasing the likelihood of future interflow conditions, which may cause reductions in hypolimnetic dissolved oxygen in future years.

Strategic Science Questions

While the recent knowledge assessment (KA) specified many science questions addressing the effects of water quality to various resources (sediment, food base, fisheries, recreation), no strategic science questions were proposed directly dealing with tracking and predicting changes in water quality in Lake Powell or Glen Canyon Dam releases. The following questions are the most critical strategic science questions related to the effects of water quality on key resources:

> **SSQ 3-5.** How is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations?
>
> **SSQ 5-1.** How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and near shore water temperatures throughout the CRE?
>
> **SSQ 5-3.** To what extent do temperature and fluctuations in flow limit spawning and incubation success for native fish?

Links/Relationships to Other Projects

The quality of dam releases and subsequent in-stream changes can have a profound effect on various aspects of the aquatic ecosystem in Grand Canyon. Temperature affects metabolic rates of various organisms, including bacteria, plants, invertebrates, and vertebrates. It also affects reproductive processes, larval development, and behavior of native and nonnative fishes. Nutrient concentrations in dam releases can influence primary productivity processes in the clear water Lees Ferry reach. Dissolved oxygen is essential to maintaining healthy fish and invertebrate populations throughout Grand Canyon. Temperature and dissolved oxygen have been shown to have most direct affect on native and nonnative fish populations. Suspended sediment concentrations limit the light available for primary productivity and affect the behavior of various fishes. Tracking status and trends of these water quality parameters forms a direct link to various food base and fishery studies currently underway in Grand Canyon.

Information Needs Addressed

The following information needs (as updated June 23, 2003) relate directly to water-quality monitoring in Lake Powell and the GCD tailwater.

CMIN 7.1.1. Determine the water temperature dynamics in the main channel, tributaries (as appropriate), backwaters, and nearshore areas throughout the Colorado River ecosystem

CMIN 7.2.1. Determine the seasonal and yearly trends in turbidity, water temperature, conductivity, DO, and pH changes in the main channel throughout the Colorado River ecosystem

CMIN 7.3.1. What are the status and trends of water quality released from GCD?

SIN 7.2.1. How do the hydrodynamics and stratification of Lake Powell influence the food base or fisheries downstream?

SIN 7.2.2. Which water quality variables influence food base and fisheries in the Colorado River ecosystem?

RIN 7.3.1. Develop simulation models for Lake Powell and the Colorado River to predict water quality conditions under various operating scenarios, supplant monitoring efforts and elucidate understanding of the effects of dam operations, climate, and basin hydrology of Colorado River water quality.

- **7.3.1.a.** Determine status and trends of chemical and biological components of water quality in Lake Powell as a function of regional hydrologic conditions and their relation to downstream releases.

- **7.3.1.b.** Determine stratification, convective mixing patterns, and behavior of advective currents in Lake Powell and their relation to GCD operations to predict seasonal patterns and trends in downstream releases

RIN 7.3.3. How do dam operations affect reservoir limnology?

SIN 7.3.1. Measure appropriate water quality parameters to determine the influence of these parameters on biological resources in the Colorado River ecosystem

EIN 7.3.1. How does the water quality of releases from GCD change in response to an experiment performed under the ROD, unanticipated event, or other management action?

Other information needs (as updated June 23, 2003) require supporting information from water-quality monitoring in Lake Powell and the GCD tailwater.

RIN 7.1.1. What are the desired ranges of spatial and temporal patterns of water temperatures for the CRE?

RIN 7.1.2. What are the most likely downstream temperature responses to a variety of scenarios involving a TCD on GCD?

RIN 7.1.3. What are the potential ecological effects of increasing mainstem water temperature?

RIN 7.2.1. Which major ions should be measured? Where and how often?

RIN 7.2.2. Which nutrients should be measured? Where and how often?

RIN 7.2.3. Which metals should be measured? Where and how often?

General Methods

Lake Powell monitoring is conducted monthly in the forebay and quarterly throughout the reservoir. Profiles of physical parameters (temperature, specific conductance, pH, dissolved oxygen, turbidity, redox potential) are collected through the water column at each site in the reservoir. Chemical (major ions and nutrients) and biological samples (chlorophyll and plankton) are collected at selected sites to characterize major strata and advective currents in the reservoir.

Glen Canyon Dam tailwater monitoring consists of continuous monitoring (temperature, specific conductance, pH, dissolved oxygen, turbidity) with monthly chemical and biological sample collection. Grand Canyon monitoring consists primarily of collection of temperature and conductance at various locations.

Monitoring parameters include temperature, conductance, pH, dissolved oxygen, redox potential, and turbidity. Chemical analyses include determination of major ionic constituents and nutrient compounds of phosphorus and nitrogen. Plankton analyses include enumeration and identification of species, biomass estimates, and relative abundance calculations. All measurements and laboratory analyses are performed in accordance with standard approved methods.

Reservoir modeling is performed in cooperation between Reclamation and GCMRC to achieve predictive capabilities and supplant or redirect some aspects of monitoring. Current model development has progressed to include calibrations for dissolved oxygen concentration, algal components, and oxygen demand from deltaic resuspension.

Products/Reports

An annual report for FY07 is in development and will be published in FY08. Periodic reports of water quality conditions will be posted via Internet in spring 2006. Updates on water quality conditions will be provided to AMWG, TWG, and other interested parties through written reports or oral presentations periodically.

Budget

Reclamation provides direct funding to GCMRC for the Lake Powell water quality monitoring program. In addition, Reclamation also provides field support for monitoring activities, both from its own staff and through a service agreement with the NPS. It also provides laboratory analyses for nutrients, major ions, and chlorophyll through a service agreement with its Lower Colorado Regional Lab in Boulder City, Nevada. Reclamation is also taking the lead in development and calibration of the CE-QUAL-W2 simulation model for Lake Powell. A table of cost estimates for FY08 follows.

BIO 7.R1.08	
Water Quality Monitoring Lake - Powell & Tailwaters (FY07–FY09)	
	Fiscal Year 2008

PHY 7.M1.08: Core Monitoring of Downstream Integrated Quality-of-Water (below Glen Canyon Dam)

The downstream integrated quality-of-water (IQW) project focuses mostly on monitoring but can also support implementation of flow research related to stable flow testing, evaluation of alternative fluctuating flows, tests of beach/habitat-building flows (BHBF) and ongoing development and evaluation of numerical modeling. In some instances, it is difficult to separate these elements from experimental elements because they support each other. For example, monitoring the suspended-sediment budget may be considered core monitoring, but it is also required to assess a trigger for a BHBF such that it could be considered experimental research support. In the section on project goals/tasks, the individual project elements are described along with the associated category(s).

Start Date

October 2007

End Date

September 2008 (This project is intended to provide core-monitoring information to meet the information needs related GCDAMP goals 7 and 8 under an ongoing schedule during FY08 and beyond).

Principal Investigator

David Topping, U.S. Geological Survey; GCMRC, Biological Resources Discipline

Geographic Scope

The downstream IQW project is primarily focused on the main channel of the Colorado River from just below GCD (river-mile -15) downstream to the upper end of Lake Mead (as measured at the above Diamond Creek gaging station at river-mile 226). In addition, an important component of the project is a combination of monitoring and modeling of tributary sediment inputs such that sediment and flow monitoring activities are also carried out in various tributary watersheds, such as the Paria River at Lees Ferry, the Little Colorado River near Cameron, Arizona, and at another site above the confluence with the mainstem Colorado River, and various lesser tributaries in Glen, Marble, and Grand Canyons.

Project Goals/Tasks

The downstream IQW monitoring project is focused primarily on measurements of surface flow throughout the river ecosystem, as well as quality-of-water parameters such as temperature, specific conductivity, dissolved oxygen, and suspended-sediment transport. The monitoring project directly supports achievement of the following GCDAMP goals:

Goal 7: Establish water temperature, quality, and flow dynamics to achieve GCDAMP ecosystem goals.

Goal 8: Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals.

Because this monitoring project addresses the physical framework of the ecosystem, which underlies many biological, cultural, and recreational resource objectives, it indirectly supports achievement of almost all other GCDAMP goals, as described below:

Goal 1: Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels.

The downstream IQW monitoring project supports this goal by providing information on flows, water temperature, and turbidity that aids in food base studies, such as the assessment of primary productivity and allochthonous inputs.

Goal 2: Maintain or attain a viable population of existing native fish, remove jeopardy for HBC and razorback sucker, and prevent adverse modification to their critical habitats.

The downstream IQW monitoring project also supports the native fish program by providing nearshore water temperature data for the assessment of growth rates, sediment concentration data that is used to adjust for catch efficiency in population models, flow and stage data that is important to understanding the effects of nearshore habitat disruption caused by fluctuating flows, and information on sandbars which create backwater habitats that are thought to be important for native fish.

Goal 4: Maintain a wild reproducing population of RBT above the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish.

The downstream IQW monitoring project also monitors dam release and Glen Canyon quality-of-water, which proved critically important in Fall 2004 when dissolved oxygen levels were low requiring modifications to release patterns in order to raise oxygen levels.

Goal 6: Protect or improve the biotic riparian and spring communities within the CRE, including threatened and endangered species and their critical habitat.

The downstream IQW monitoring project also tracks the transport and fate of fine sediment, which provides the substrate for riparian vegetation and marsh communities.

Goal 9: Maintain or improve the quality of recreational experiences for users of the CRE within the framework of GCDAMP ecosystem goals.

The downstream IQW monitoring project also produces monitoring data and supports experimental and modeling research to understand flow dynamics and the size and abundance of sandbars, which are resources that affect the recreational experiences of Colorado River users such as rafters and fishermen.

Goal 11: Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations.

The downstream IQW monitoring project also provides monitoring data related to riverine sandbars that provide a source of sediment, through aeolian transport, to high elevation sand deposits that contain archaeological resources. In addition, the downstream IQW monitoring project has also developed stage modeling capabilities that allow for the assessment of the flow level that inundates a given cultural site.

In August 2004, the AMWG reviewed these goals and identified priority questions. The top five priority questions are as follows:

Priority 1: Why are HBC not thriving, and what can we do about it? How many HBC are there and how are they doing?

Priority 2: Which cultural resources, including TCPs, are within the Area of Potential Effect (APE), which should we treat, and how do we best protect them? What is the status and trends of cultural resources and what are the agents of deterioration?

Priority 3: What is the best flow regime?

Priority 4: What is the impact of sediment loss and what should we do about it?

Priority 5: What will happen when a TCD is tested or implemented? How should it be operated? Are safeguards needed for management?

As with the GCDAMP goals, the downstream IQW monitoring project directly supports some priorities while indirectly supporting others. For example, monitoring and research on flows, sediment transport, and water temperature clearly directly support priorities 3, 4, and 5, while also indirectly supporting priorities 1 and 2 by providing information on the general physical framework of the riverine environment.

There are several project-related tasks that occur within the downstream IQW monitoring project:

Flow and Stage Monitoring

Continued monitoring of flow and stage at established mainstem locations and major tributaries (-15-mile, 0-mile, 30-mile, 61-mile, 87-mile, 166-mile, 226-mile, Paria River at HWY 89 bridge and near Lees Ferry, and two sites on the Little Colorado River). Category(s): Core Monitoring. Schedule: Ongoing. Official surface water records are collected and published by Utah Water Science Center of USGS at: Paria River at the HWY 89 bridge. Official surface water records are collected and published by Arizona Water Science Center of USGS at the following tributary gage sites: Paria River near Lees Ferry, LCR near Cameron, LCR above the mouth near Desert View, as well as Kanab Creek near Kanab and Havasu Creek above the mouth near Supai and at the following mainstem gages: 0-Mile, 87-Mile and 226-Mile. The -15-Mile flow measurements are reported by the Bureau of Reclamation.

Quality-of-Water Monitoring

Continued monitoring of water temperature at established mainstem locations and major tributaries (-15-mile, 0-mile, 30-mile, 61-mile, 87-mile, 166-mile, 226-mile, 246-mile, Paria River at Lees Ferry and two sites on the Little Colorado River, as well as Kanab and Havasu Creeks). Continuation of a new nearshore/backwater temperature monitoring program. Continued monitoring of conductivity at established stations (-15-mile, 0-mile, 30-mile, 61-mile, 87-mile, 226-mile). Continued monitoring of turbidity at established stations (30-mile, 61-mile, 226-mile).Category(s): Core Monitoring. Schedule: Ongoing for mainstem temperature, conductivity, and turbidity monitoring; continuation of nearshore/backwater monitoring program in FY08, then ongoing; monitoring data supports completion of downstream thermal model development during FY08, applications ongoing.

Suspended-sediment Flux Monitoring

Continued monitoring of suspended-sediment flux at established mainstem locations and major tributaries (30-mile, 61-mile, 87-mile, 166-mile, 226-mile, Paria River at Lees Ferry and one site along the Little Colorado River [near Cameron, AZ]). Because BHBF triggers are based on sediment retention within the mainstem, it is insufficient to monitor tributary inputs only. Category(s): Core Monitoring. Schedule: Ongoing.

Collaboration with and Support of Aquatic Food Base Program

Integrated research studies with the aquatic food base program, including submerged aquatic vegetation and bed texture classification with acoustics, monitoring algal drift with acoustics, and quantification of tributary inputs of organic material. Category(s): Support for Research and Development. Schedule: Ongoing.

Coordination with Other Resource Areas

Regular meetings and interaction with other resource area personnel, particularly at the Program Manager level, in order to facilitate an ecosystem approach to our scientific studies and ensure that the downstream IQW monitoring project is providing useful information regarding the physical environment to the other resource areas. Category(s): Program Management. Schedule: Ongoing.

Need for the Project

Information on flow, water quality, and suspended-sediment transport is critical to understanding the physical environment upon which biological and sociocultural resources depend (see details in Section 1 of this project description). In order to understand responses of these resources to dam operations, we must first understand the effects of dam operations on the physical environment. The goal of the downstream IQW project is to provide this information and link dam operations to changes in the physical environment.

Strategic Science Questions

The downstream IQW monitoring project is designed with the goal of providing data that supports answering the two primary physical resources questions identified during the knowledge assessment workshop (KAW) conducted in the summer of 2005, as follows:

> **SSQ 4-1.** Is there a “Flow-Only” operation (i.e. a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal time scales?
>
> **SSQ 5-1.** How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and near shore water temperatures throughout the CRE?

Also, as detailed throughout this project description, the downstream IQW monitoring project provides information on the physical environment that is critical to other resource areas and will thus contribute indirectly to answering a variety of other science questions related to other resources.

Links/Relationships to Other Projects

Aquatic Food Web Research

The downstream IQW monitoring project supports new research focused on the food web of the river ecosystem by providing continuous data on surface flow in the main channel and major tributaries, as well as related quality-of-water data, such as water temperature, specific conductivity, dissolved oxygen and suspended-sediment concentrations and grain size for suspended particles in transport.

Fisheries Monitoring and Research

The downstream IQW monitoring project also supports science activities in the fisheries program by providing flow and quality-of-water data that may be used by the fisheries biologist in evaluating their fish catch data, as well as growth, movement and habitat use information.

Information Needs Addressed

The downstream IQW monitoring project directly addresses several of the CMINs and RINs related to GCDAMP goals 7 and 8. A selection of the information needs that are addressed by downstream IQW monitoring project are listed below. The downstream IQW monitoring project addresses many more CMINS, but the ones listed below are considered most relevant to answering the science questions outlined above.

> **CMIN 7.4.1.** Determine and track flow releases from GCD under all operating conditions.
>
> **CMIN 7.1.2.** Determine and track LCR discharge and temperature near the mouth (below springs).
>
> **CMIN 7.1.1.** Determine the water temperature dynamics in the mainstem, tributaries, backwaters, and nearshore areas throughout the CRE.
>
> **CMIN 8.1.3.** Track, as appropriate, the monthly sand and silt/clay -input volumes and grain-size characteristics, by reach, as measured or estimated at the Paria and Little Colorado River [near Cameron and above the confluence] stations, other major tributaries like Kanab and Havasu Creeks, and “lesser” tributaries?
>
> **CMIN 8.1.2.** What are the monthly sand and silt/clay export volumes and grain-size characteristics, by reach, as measured or estimated at Lees Ferry, Lower Marble Canyon, Grand Canyon, and Diamond Creek Stations?

The monitoring data from the downstream IQW monitoring project not only fulfill the CMINs listed above, but are also intended to feed new information directly into modeling efforts (see PHY 07.R1.08) that will allow sediment-transport modelers the opportunity to address RINs related to GCDAMP goals 7 and 8.

> **RIN 7.4.1.** What is the desired range of seasonal and annual flow dynamics associated with power plant operations, BHBFs, and habitat maintenance flows, or other flows that meet GCDAMP goals and objectives?

RIN 7.3.1. Develop simulation models for Lake Powell and the Colorado River to predict water quality conditions under various operating scenarios, supplant monitoring efforts, and elucidate understanding of the effects of dam operations, climate, and basin hydrology on Colorado River water quality.

RIN 8.5.1. What elements of ROD operations (upramp, downramp, maximum and minimum flow, Modified Low Fluctuating Flow (MLFF), High Modified Flow (HMF), and BHBF) are most/least critical to conserving new fine-sediment inputs, and stabilizing sediment deposits above the 25,000 cfs stage?

General Methods

Flow, stage, water temperature, conductivity, turbidity and suspended-sediment data are collected using standard USGS protocols with QA/QC (described in *Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 3, Sections A and C*). Suspended-sediment sampling is supplemented through the use of emerging technologies, including acoustics and laser-diffraction (Melis and others, 2003; Topping and others, 2004, 2006, in press). Stage, water temperature, conductivity, turbidity, and suspended-sediment surrogates (i.e. acoustics and laser-diffraction) are monitored with in-situ instrumentation recording at 15-minute intervals. River flow is measured episodically and used to develop a stage-discharge rating curve, providing 15-minute flow records (described in *Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 3, Section A*). Similarly, suspended-sediment concentration is measured episodically and used to calibrate and acoustic and laser diffraction instrumentation, providing 15-minute records of concentration (sand, silt/clay, and sand grain-size).

Products/Reports

The following products/reports are expected on an annual basis:

Streamflow, stage, and tributary sediment data published in annual Arizona and Utah Water Resources Data reports [surface water and sediment records published by the Utah and Arizona Water Science Centers] and served through the GCMRC Web page [data delivered on or before February 28, 2009],

Biennial Data Report summarizing mainstem sediment transport and water-quality data; data also served through the GCMRC Web page [GCMRC leads in preparing these reports]

2–4 conference abstracts and proceedings articles

1–3 journal articles

Frequent presentations at stakeholder meetings

Budget

PHY 7.M1.08	
Downstream Integrated Quality-of-Water Monitoring (FY08–Ongoing Core Monitoring)	
	Fiscal Year 2008

PHY 7.R1.08: Modeling Support Linked with Downstream Integrated Quality-of-Water Monitoring Project (below Glen Canyon Dam)

The modeling support activity linked with the Downstream Integrated Quality-of-Water (IQW) project focuses on advancement of simulation capabilities needed to predict the fate of flow releases from GCD and associated water quality constituents such as temperature and suspended sediment. This sub-element of the downstream IQW monitoring project is intended to refine existing models that are being developed to predict downstream thermal regimes, as well as the fate of fine-sediment inputs that enter the ecosystem from sources such as the Paria and Little Colorado Rivers.

Start Date

October 2006

End Date

Continuing. This project parallels the downstream IQW monitoring project and it is expected that support for model development and improvements will continue in parallel to the monitoring program. As new data are collected, existing models can be continuously tested, improved, and applied.

Principle Investigator(s)

Scott A. Wright, U.S. Geological Survey, Water Resources Discipline, Mark Schmeeckle, Arizona State University, David M. Rubin, U.S. Geological Survey, Geological Discipline, David J. Topping, U.S. Geological Survey, Biological Resources Discipline

Geographic Scope

For the most part, the modeling support activities are linked to the IQW project in a spatially parallel way and are, therefore, also focused on the main channel of the Colorado River ecosystem, between Glen Canyon Dam (mile -15) to Diamond Creek (mile 226). However, an important component of the downstream IQW is a combination of monitoring and modeling of tributary sediment inputs such that research and monitoring activities are carried out in various tributary watersheds as well, such as the Paria and Little Colorado Rivers. Because of this, the proposed modeling activities are also tied to monitoring efforts within these two major tributaries, particularly related to model simulations that predict sand production during runoff events.

Project Goals/Tasks

Ongoing development of models to simulate flow, sediment transport, and downstream water temperature are intended to be closely interfaced with ongoing monitoring activities throughout the science program. As stated in the previous section, the downstream IQW monitoring project (Project PHY 07.M1.08) is focused primarily on measurements of surface flow throughout the river ecosystem as well as quality-of-water parameters such as temperature, specific conductivity, dissolved oxygen, and suspended-sediment transport. As described in the section on Project PHY 07.M1.08, the monitoring project directly supports achievement of the following GCDAMP goals:

Goal 7: Establish water temperature, quality, and flow dynamics to achieve GCDAMP ecosystem goals.

Goal 8: Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals.

The specific modeling tasks for FY08 are as follows:

Continued support for the development of nearshore temperature models: Under the assumption that the development of nearshore temperature models will continue to be funded through a separate agreement with Reclamation (TCD funds), P.I. Wright will provide support and guidance to GCMRC hydrologist Craig Anderson in this endeavor. In particular, in coordination with the second task outlined below, P.I. Wright will evaluate available multi-dimensional models, in particular Delft-3D, for use in nearshore temperature modeling. Category(s): Research & Development. Schedule: Ongoing.

Sediment transport modeling of eddy-sandbar environments: This is one of the primary recommendations of the external review panel from the Sediment Transport Modeling Review Workshop conducted in Santa Cruz, CA, on February 15–16, 2007[1]. This is only one of the many recommendations made by the review panel; however, budget constraints dictate that not all recommendations can be addressed in FY08. There is currently a need to further our understanding of how sediment is exchanged between the main channel and eddy-sandbars as well as how sandbars build and erode under various flows and sediment supply. Reliable predictions of the area and volume of eddy-sandbar deposits requires improvement in this area. Further, improvements in the one-dimensional routing model, as recommended by the Modeling Review Panel, can be facilitated by improving the parameterization of sandbar deposition and erosion mechanics through the use of multi-dimensional models. Various readily available multi-dimensional models will be evaluated for use in Grand Canyon. Also, existing datasets will be assessed to determine the need for further field data collection and/or laboratory experiments. Once applicable models are chosen and datasets are selected and/or collected, the datasets and models will be used to further our understanding of how eddy-sandbars form and evolve under a variety of flow and sediment supply conditions. The results from these modeling exercises will be used to improve one-dimensional sand routing algorithms as well as to evaluate the effects of various dam operations (e.g., BHBFs, ramping rates) on eddy-sandbar deposits. Category(s): Research and Development. Schedule: Ongoing, through at least FY08.

Need for Project

Information on flow, water quality, and suspended-sediment transport is critical to understanding the physical environment upon which biological and socio-cultural resources depend (see details Project PHY 07.M1.08 description). In order to understand responses of these resources to dam operations, we must first understand the effects of dam operations on the physical environment. The goal of the modeling support activities linked to the downstream IQW monitoring project is to provide increased predictive capabilities (simulations) that can be used

[1] Simoes, F.J., Goodwin, P., Hanes, D.M., Sherwood, C., Schoellhamer, D.H., and Sloff, K., 2007. Final Report of the External Review Panal, Sediment Transport Modeling Review Workshop, U.S. Geological Survey Grand Canyon Monitoring and Research Center Administrative Document, 14 p.

as planning tools for linking dam operations to changes in the physical environment, as well as exploring interdisciplinary relationships with biological, cultural economic and recreational elements of the GCDAMP.

The GCMRC works in conjunction with Reclamation on development of the CEQUAL-W2 model by providing monitoring data that is used for model calibration and verification. This monitoring data consists of information describing the quality of water in Glen Canyon Dam releases, Lake Powell, and tributary inflows into Lake Powell. In addition, the GCMRC has provided comments on the direction of model development so that a product that can be developed that meets the needs of the GCMRC program. Reclamation has had at least two people working on model development and it has been felt that actual model development should rest with Reclamation, rather than have the GCMRC pursue a redundant modeling effort. It is recognized that once a functional model is in place, the different entities involved will have different questions to be addressed by the model. While model development is in progress and a full-functioning model is not yet in place, many components of the water-quality monitoring program can be addressed with results from the model, such as identifying parameters for which the model is more or less sensitive and restructuring monitoring efforts appropriately. Examples are identifying the need for more detailed inflow water-quality monitoring, establishment and maintenance of additional meteorological stations and the reservoir, and modifying sampling methods for biological parameters such as chlorophyll and plankton, in order to refine the model's ability to simulate productivity processes.

Strategic Science Questions

The downstream IQW modeling activities are designed with the objective of providing predictive capability that supports answering the two primary physical resources questions identified during the Knowledge Assessment Workshop conducted in the summer of 2005, as follows:

Is there a “Flow-Only” operation (i.e. a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal time scales?

How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and near shore water temperatures throughout the CRE?

Both of the above questions can be only partially addressed through collection of monitoring data. Likewise, both questions are related to issues that can be at least partially resolved through focused experimental research in combination with ongoing modeling research activities. Following collection of monitoring data in Project PHY 07.M1.08, development and refinement of the models for simulating flow, suspended-sediment transport, and downstream temperature evolution is the next step toward resolving these critical questions in the next phase of monitoring and research.

Links/Relationship to Other Projects

Because ongoing modeling efforts are linked to the downstream IQW monitoring project, it is also intended to address and support elements of the physical framework of the ecosystem, which underlies many biological, cultural, and recreational resource objectives. As a result, the modeling efforts scheduled indirectly support achievement of almost all other GCDAMP goals, as described in the previous section on Project PHY 07.M1.08. The ongoing activities associated with development of simulation capabilities and verification of existing models already in existence can effectively benefit from the collection of monitoring data from the downstream IQW project. These simulation models include flow routing, suspended-sediment transport, sand bar evolution, and downstream thermal simulations throughout the main channel. Having predictive capabilities for physical

resources related to dam operations is potentially a valuable support tool in planning future experimental treatments, as well as evaluating proposed management actions in the river ecosystem that generally relate to GCDAMP Goal 1, Goal 2, Goal 4, Goal 6, Goal 9, and Goal 11. In addition, Goal 12 is also supported by efforts to advance modeling activities for the ecosystem.

Aquatic Food Web Research: Both the downstream IQW monitoring project and its modeling support link to thermal and suspended-sediment transport can help to support new research focused on the food web of the river ecosystem by providing continuous data on surface flow in the main channel and major tributaries, as well as related quality-of-water data, such as water temperature, specific conductivity, dissolved oxygen, and suspended-sediment concentrations and grain size for suspended particles in transport, but also by providing simulations for predicting downstream boundary conditions that limit in-stream productivity.

Fisheries Monitoring and Research: The downstream IQW modeling activities provide support beyond IQW data by making simulations for physical habitat changes, such as backwaters, available to fishery scientists before future BHBF tests. Such information can assist scientists in planning better integrated studies.

Information Needs Addressed

The modeling support sub-element of the downstream IQW directly addresses several of the research information needs (RINs) related to AMP Goals 7 and 8.

RIN 7.4.1: What is the desired range of seasonal and annual flow dynamics associated with power plant operations, BHBFs, and habitat maintenance flows, or other flows that meet GCDAMP goals and objectives?

RIN 7.3.1: Develop simulation models for Lake Powell and the Colorado River to predict water quality conditions under various operating scenarios, supplant monitoring efforts, and elucidate understanding of the effects of dam operations, climate, and basin hydrology on Colorado River water quality.

RIN 8.5.1: What elements of Record of Decision operations (upramp, downramp, maximum and minimum flow, MLFF, HMF, and BHBF) are most/least critical to conserving new fine-sediment inputs, and stabilizing sediment deposits above the 25,000 cfs stage?

General Methods

The method used for verification of the existing flow, sediment, and thermal models will vary from one model to another, depending upon how managers and scientists propose to use the models to support planning activities. Generally, historical monitoring data will be used in combination with real or projected boundary conditions for the ecosystem (on a reach-scale basis) to determine how accurately models can re-create conditions measured around specific flow periods or events, such as the fate of Paria River sand inputs, BHBF releases, etc. For downstream temperature simulations, model behavior will be evaluated and compared to measured responses for purposes of testing and calibrating the temperature model. Additional meteorological data (if available) may also be added to the model to further evaluate performance with respect to historical patterns. Projected release patterns for flow and temperature (from the Lake Powell model) shall also be used to evaluate future conditions of downstream temperature in the main channel and along near-shore habitats.

Products/Reports

The following products/reports are expected:

Development and documentation of nearshore water temperature modeling capabilities, including simplified "pond" backwater models and detailed multi-dimensional models of areas with available bathymetry (By end of calendar year – December 31, 2009).

Development and documentation of multi-dimensional models of eddy-sandbar environments. Evaluation and summary of available datasets for sediment transport and morphology of eddy-sandbar environments (By end of calendar year – December 31, 2009).
One or more conference abstracts and/or proceedings articles per year

One or more journal articles per year

Presentations at GCDAMP stakeholder meetings as necessary.

Budget

PHY 7.R1.08	
Modeling Support Linked with Downstream Integrated Quality-of-Water Monitoring	
	Fiscal Year 2008

GCDAMP Goal 8: Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve the Adaptive Management Program ecosystem goals.

PHY 8.M1.08: Core Monitoring for the Sediment Budget and Sandbar Status Throughout the CRE Utilizing Direct Topographic/Bathymetric Measurements and Remote Sensing (short title: SED TREND).

Start Date

October 2007

End Date

Ongoing

Principal Investigator(s)

Roderic Parnell, Matt Kaplinski, Joseph E. Hazel, Jr., Department of Geology, Northern Arizona University; David J. Topping, US Geological Survey, GCMRC; and David M. Rubin, US Geological Survey, Coastal and Marine Team, Santa Cruz, CA in coordination with GCMRC program managers for Physical/Modeling, Biology, Socio-Cultural and Logistics/Survey, as well as other staff scientists

Geographic Scope

The SED TREND monitoring is focused on detecting long-term (i.e., 4-year to multi-decadal) trends in the Colorado River ecosystem (CRE) sediment budget for both fine (sand and finer material) and coarse sediment. In addition, this project utilizes a combination of direct topographic measurement and remote sensing to monitor the status of high-elevation (> the stage associated with a discharge of 8,000 ft^3/s) sandbars on an annual to 4-year basis. The annual topographic measurements of high-elevation sandbars are covered under project REC 9.R1.08: Sandbar and Campable Area Monitoring under goal 9 (see below). The remote-sensing aspect of the SED TREND monitoring **will not** occur during FY08, but is scheduled as part of the 2007–11 Monitoring and Research Plan, with implementation in FY09–FY10. The total geographic extent of this monitoring is from Glen Canyon Dam to the upper end of Lake Mead (near Separation Canyon). During FY08, SED TREND monitoring will focus on river-miles 0 (Lees Ferry) through 30; this segment of the CRE is referred to herein as Upper Marble Canyon.

Project Goals/Tasks

The SED TREND monitoring directly supports achievement of the following GCDAMP goals:

Goal 8 – Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve AMP ecosystem goals.

Goal 9 – Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem within the framework of AMP ecosystem goals. The SED TREND monitoring provides information on the size and abundance of sandbars, which are resources that affect the recreational experiences of Colorado River users.

Goal 11 – Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations. The SED TREND monitoring is the project that collects information on the

sandbars that provide a source of sediment, through aeolian transport, to high elevation sand deposits that contain archaeological resources.

Because SED TREND monitoring addresses the physical framework of the ecosystem, which underlies many biological resource objectives, it also indirectly supports achievement of the following four AMP goals:

Goal 1 – Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels. The SED TREND monitoring supports this goal by providing information on coarse sediment inputs which provide the substrate for parts of the aquatic food base.

Goal 2 – Maintain or attain a viable population of existing native fish, remove jeopardy for humpback chub and razorback sucker, and prevent adverse modification to their critical habitats. The SED TREND monitoring supports this goal by providing information on sandbars which create backwater habitats that are thought to be important for native fish.

Goal 6 – Protect or improve the biotic riparian and spring communities within the Colorado River ecosystem, including threatened and endangered species and their critical habitat. The SED TREND monitoring monitors the status of the fine-sediment deposits which provides the substrate for riparian vegetation and marsh communities.

The primary objective of the Goal 8 SED TREND monitoring is to determine magnitudes and trends in fine-sediment storage throughout the CRE in the main channel and eddies at all elevations, specifically broken down into bins below the stage associated with a discharge of 8,000 ft^3/s (where over 90% of the fine sediment in the CRE is typically stored), between the stages associated with discharges of 8,000 and 25,000 ft^3/s, and above the stage associated with a discharge of 25,000 ft^3/s.

The secondary goals of this project are to determine magnitudes and trends in campsite area and distribution (this supports Goal 9), backwater geometry (area plus depths) and distribution (this supports Goal 2), and the availability of open dry sand on sandbars that can be transported by the wind upslope into archeological sites thereby helping preserve these resources (this supports Goal 11).

These multi-goal objectives are proposed to be met through the following three monitoring tasks on an annual to quadrennial basis, in keeping with managers' information needs.

SED TREND Task #1

ANNUAL EFFECTIVENESS MONITORING FOR HIGHER ELEVATION SAND DEPOSITS - (sub-sample of sandbar with emphasis on campsite areas) monitoring of the area and volume of fine sediment above the stage associated with 8,000 ft^3/s for subsets of sandbars and campsites throughout the CRE using conventional ground-based surveying methods. This dataset is commonly referred to as the "NAU sandbar time series" and is the longest running dataset on the state of sandbars currently available (initiated in 1990). This task is conducted in coordination with Goal 9 core monitoring and will take place in the fall of each year. **Task #1, is covered under project REC 9.R1.08: Sandbar and Campable Area Monitoring under goal 9 (see below).**

SED TREND Task #2

REPEAT SYSTEM-WIDE INVENTORY OF HIGHER ELEVATION SAND DEPOSITS - Approximately every 4 years (but only in years without BHBFs, see "Schedule by task" section below for details),

monitoring of systemwide area and volume of fine sediment (especially open sand) above the stage associated with a discharge of 8,000 ft^3/s (i.e., approximately 10% of the fine sediment in the CRE) based on aerial overflight data (LiDAR and orthrectified hyperspectral aerial photography). These remote-sensing data are also used to help monitor the magnitude and trends in campsite area, backwater area and distribution, the availability of open dry sand on sandbars, as well as for other resource areas such as riparian vegetation monitoring. These data will also be used to help quantify the inputs of gravel from tributaries. These gravel inputs provide important substrate for the aquatic food web. **Task #2, will not occur during FY08; but would occur in coordination with the next planned remote-sensing overflight scheduled for FY09.**

SED TREND Task #3

ANNUAL REPEAT MAPPING OF LOWER ELEVATION CHANNEL SAND DEPOSITS - Annually (but only in years without BHBFs, see "Schedule by task" section for details), monitoring the area and volume of fine sediment at all elevations over long reaches using multi-beam bathymetric surveys, ground-based topographic surveys, underwater video transects, and limited underwater microscope data collection for bed grain size. Ideally, this task would be performed on a systemwide basis every 5–10 years in order to estimate fine sediment budgets over time scales for which the Goal 7 mass balance sediment budgets likely become inconclusive due to accumulating measurement errors. However, since it is currently logistically impossible to survey the bathymetry of the entire river in any given year, surveys will be completed annually of sections of the river with a different section surveyed each year on a rotating basis. The sections (or reaches) will correspond to the same reaches outlined in the Goal 7 mass balance core monitoring project (Fig. 2), as follows: Reach 1 – RM0 to RM30 (upper Marble Canyon); Reach 2 – RM30 to RM61 (lower Marble Canyon); Reach 3 – RM61 to RM87 (eastern Grand Canyon); Reach 4 – RM87 to RM166 (central Grand Canyon); Reach 5 – RM166 to RM226 (western Grand Canyon, see Fig. 1).

These reach surveys will occur in the late spring and will only be completed in years without BHBFs (see "Schedule by task" section for details); thus, in the absence of BHBFs each reach would be surveyed every 5 years, or, if BHBFs occurred on average every other year, then each reach would be surveyed on average every 10 years. The 5–10 year interval is considered by sediment scientists to be sufficient to detect long-term trends in the fine sediment budget based on changes in topography and bathymetry. Finally, since some reaches are longer than others, it is possible that some reaches will be too long to survey completely in a single river trip (e.g. Reaches 4 and 5); for these reaches, available side-scan sonar data will be used to identify the portions of these reaches that are most likely to store fine sediment. It is also possible that continued technological advancements and improvements in methods will allow for complete surveys of these reaches in the future. In addition to providing key sediment budget information (i.e., the status of the fine-sediment "bank account"), these data will provide information on the location and geometries of backwaters thought to be important habitat for native fish. **Task #3, is the focus of this narrative proposed for FY08 SED TREND monitoring.**

The schedule for SED TREND monitoring under Goal 8 is complicated by the potential for BHBFs, except for Task 1 sandbar and campsite surveys which will occur annually in the fall whether or not a BHBF is scheduled **(covered under project REC 9.R1.08: Sandbar and Campable Area Monitoring under Goal 9)**. For Task 2, remote sensing missions and Task 3 reach surveys, it is advantageous to have these occur in years without BHBFs so that the monitoring data are not dominated by the effects of a single BHBF (BHBF monitoring is described under a separate science plan developed by the GCMRC in 2007). Rather, the remote sensing and reach survey monitoring should represent the integral response of the system to several years of dam operations and tributary inputs. Further, logistical constraints would make it difficult to conduct the remote sensing and reach survey core monitoring in addition to the BHBF monitoring. Thus, without knowing the exact frequency of BHBFs, it is impossible to outline the exact schedule for Goal 8 SED TREND monitoring.

It is possible, though, to outline potential schedules based on assumptions regarding BHBF frequency. In the table below, two possible 10-year schedules are outlined for illustrative purposes. The first is the schedule in the absence of BHBFs where the exact schedule can be delineated. The second schedule assumes that BHBFs occur every other year, which would be the approximate frequency under previous triggers based on tributary sediment supply. In reality, even if the frequency were every other year on average, there would likely be periods with successive years of BHBFs and successive years without BHBFs such that the core monitoring schedule for remote sensing and reach surveys must be flexible.

SED TREND Tasks	**Schedule without BHBFs**			**With BHBFs every other year**		
Year	**Task 1: Subsample Campsites/ sandbars**	**Task 2: 4-year Over flights**	**Task 3: Flux-Reach surveys**	**Task 1: Subsample Campsites/ sandbars**	**Task 2: 4-year Over flights**	**Task 3: Flux-Reach surveys**
2008	X		X (R1)	X		X (R1)
2009 (BHBF)	X	X	X (R2)	X		
2010	X		X (R3)	X	X	X (R2)
2011 (BHBF)	X		X (R4)	X		
2012	X		X (R5)	X		X (R3)
2013 (BHBF)	X	X	X (R1)	X		
2014	X		X (R2)	X	X	X (R4)
2015 (BHBF)	X		X (R3)	X		
2016	X		X (R4)	X		X (R5)
2017 (BHBF)	X	X	X (R5)	X		

Need for Task #3 of SED TREND Monitoring

Sediment forms the physical template for the Colorado River ecosystem downstream from Glen Canyon Dam (U.S. Department of the Interior, 1995; National Research Council, 1996). The endangered and threatened native fishes evolved in a highly turbid river (Gloss and Coggins, 2005), with turbidity predominantly due to suspended silt and clay, and to a lesser degree suspended sand. Before the closure of Glen Canyon Dam, 60% of upstream sediment supply from the Colorado River in Glen Canyon was silt and clay (Topping and others, 2000). Closure of Glen Canyon Dam reduced the supply of silt and clay by about 96% at the upstream boundary of Grand Canyon National Park, with the Paria River now the major supplier of silt and clay at this location (Topping and others, 2000). The post-dam Colorado River in Marble and Grand Canyons is much less turbid (with clearer-water conditions than ever occurred naturally) and, because the in-channel storage of sand, silt, and clay in the post-dam Colorado River is greatly reduced from predam conditions, the Colorado River in the CRE is only now turbid during periods of tributary activity downstream from the dam.

Sandbars and other sandy deposits in and along the Colorado River in Grand Canyon National Park were an integral part of the natural riverscape, and are important for riparian habitat, native fish habitat, protection of archeological sites, and recreation (Rubin and others, 2002; Wright and others, 2005). Recent work has shown

that the low-elevation parts of these sandbars (< the stage associated with a discharge of 8,000 ft^3/s) in lateral recirculation eddies contain the bulk of the sand, silt, and clay in storage (Hazel and others, 2006), and the surface grain size of these sandbars is the dominant regulator of sand transport over multi-year timescales (Topping and others, 2005). Thus, the low-elevation parts of sandbars and the channel (as will be shown below) comprise the long-term "bank account" for sediment in the CRE. These deposits have eroded substantially following the 1963 closure of Glen Canyon Dam that reduced the supply of sand at the upstream boundary of Grand Canyon National Park by about 94% (Topping and others, 2000). In response to this reduction in sand supply and the alteration of the natural hydrograph by dam operations (Topping and others, 2003), sandbars in Marble Canyon and the upstream part of Grand Canyon have substantially decreased in size since closure of the dam (Schmidt and others, 2004) and are still in decline under normal power plant operations at the dam (Wright and others, 2005).

A major outstanding question is whether repeated BHBFs conducted under sediment-enriched conditions (such as those that existed during the 2004 BHBF test) can result in the rebuilding and maintenance of sandbars throughout the CRE. Scour of the low-elevation eddy and channel pool environments during sand-depleted BHBF tests, such as the 1996 Controlled Flood, is not subsequently offset by deposition of new sand under normal power plant releases (Schmidt and others, 2004; Topping and others, 2006). 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. This net decrease in low-elevation fine-sediment volume occurred despite the fact tributary inputs of sand during this period were well above average. Thus, controlled floods conducted under sediment-depleted conditions, such as those that existed in 1996, cannot be used to sustain sandbar area and volume. In addition, the dominant response (downstream from the upstream half of Marble Canyon) during the 2004 BHBF test was that eddies lost sand (although less than was gained in upper Marble Canyon). By definition, if BHBFs are to be a successful tool for the rebuilding and maintenance of sandbars in the CRE, then the volume of fine sediment stored at lower elevations (i.e., in the long-term fine-sediment ''bank account'') must not decrease over longer timescales as a result of the occurrence of repeated BHBFs.

Computing fine-sediment budgets for various reaches in the CRE (Fig. 2) over long (i.e, decadal or longer) timescales is required for evaluating the effects of dam operations, including BHBFs. Over shorter timescales (up to perhaps several years), this is best done by the "mass balance" approach described in the section on Goal 7 of the Draft Core Monitoring Report. However, because of the increasing uncertainties over time associated with the "mass balance" approach, another approach is needed to track the fine-sediment budget for the CRE over longer timescales. This other complimentary approach (described herein) is required to evaluate whether future dam releases (including BHBFs) continue to mine the sediment "bank account" or whether this bank account (stored largely at elevations less than the stage associated with a discharge of 8,000 ft^3/s) remains stable or increases under future dam releases. If the amount of sediment in this "bank account" continues to decrease, then operations will ultimately not be able to sustain the fine-sediment resources at higher elevations.

At the 2004 AMWG priority-setting workshop, questions relating specifically to sediment (and tracked by the herein described SED TREND monitoring) were identified under three of the top five priorities of the AMP. These priorities were, in decreasing order of relevance to sediment:

- GCDAMP Priority 4: What is the impact of sediment loss and what should we do about it?
- GCDAMP Priority 3: What is the best flow regime?
- GCDAMP Priority 2: Which cultural resources, including Traditional Cultural Properties (TCP), are within the Area of Potential Effect, which should we treat, and how do we best protect them? What is the status and trends of cultural resources and what are the agents of deterioration?

Strategic Science Questions

Several strategic science questions (SSQ) were identified by scientists and managers during the Knowledge Assessment Workshop conducted in the summer of 2005 (Melis and others, 2006). The SED TREND monitoring project provides valuable information to help answer several of the questions related to sediment conservation, and in particular the primary sediment question:

> **SSQ 4-1.** Is there a "Flow Only" operation (i.e., a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal time scales?

Links/Relationships to Other Projects

The SED TREND monitoring provides data (i.e, the maps showing the topography and distribution of sediment types over ~30-mile reaches of the river) that is essential to the development and testing of numerical predictive models of discharge, stage, sediment transport, and sandbar morphology. These predictive models can be used to evaluate a wide range of resource responses, such as the fate of sandbar habitats, to various dam release scenarios, such as controlled floods, steady flows, fluctuating flows, etc.

The SED TREND monitoring provides the data used to evaluate the effectiveness of dam operations (including BHBFs) on rebuilding and maintaining sandbars in the CRE. Additionally, the SED TREND monitoring will provide the data showing whether dam operations continue to mine the long-term fine-sediment "bank account" stored at elevations below the stage associated with a discharge of 8,000 ft^3/s (over 90% of the fine sediment in the system is currently stored below this elevation). If the amount of sediment in this "bank account" continues to decreases, then operations will ultimately not be able to sustain the fine-sediment resources at higher elevations.

The SED TREND monitoring supports the campsite inventories conducted under Goal 9 by characterizing the status and trends of the sandbars used as campsites **(covered under project REC 9.R1.08: Sandbar and Campable Area Monitoring under goal 9)**.

The SED TREND monitoring supports Goal 11 by characterizing the status of fine sediment at higher elevations in and around cultural sites, and by characterizing the amount of open dry sand available to be transported by the wind into these cultural sites (thereby helping preserve these sites). **(This aspect of this project will occur during FY09 when the next remote sensing mission is scheduled)**.

The SED TREND monitoring also supports new research focused on the food web of the river ecosystem by providing data on the input of gravel used as a substrate by the aquatic food web. **(This aspect of this project will occur during FY09 when the next remote sensing mission is scheduled)**

The SED TREND monitoring also provides information on the distribution of the fine sediment deposits that form the substrate for the riparian ecology.

Finally, the SED TREND monitoring supports science activities in the fisheries program by providing the data (as part of the long ~30-mile data collection effort described under Task 3) to characterize the locations and geometries of backwaters though to be important habitat for native fish.

Information Needs Addressed

The 2003 AMP Strategic Plan identified Core Monitoring Information Needs (CMINs) related to sediment storage (Goal 8). The CMINS that are addressed by the SED TREND monitoring are listed below. For each, the prioritization ranking applied by the AMP Science Planning Group in 2006 is also included. The SED TREND monitoring during FY08 will directly addresses the third of the top five Goal 8 CMIN priorities; the first two of these five are addressed by the mass balance project described under Goal 7.

CMIN 8.1.1 – Determine and track the biennial fine-sediment volume and grain-size changes in the main channel below 5,000 cfs stage, by reach. **#3 ranked Goal 8 CMIN.**

CMIN 8.4.1 – Track, as appropriate, the biennial or annual sandbar area, volume and grain-size changes within eddies between 5,000 and 25,000 cfs stage, by reach. . **#4 ranked Goal 8 CMIN.**

CMIN 8.5.1 –Track, as appropriate, the biennial sandbar area, volume and grain-size changes above 25,000 cfs stage, by reach. **#5 ranked Goal 8 CMIN.**

During FY08, the SED TREND monitoring also addresses these unranked Goal 8 CMINs.

CMIN 8.2.1 – Track, as appropriate, the biennial or annual sandbar area, volume and grain-size changes outside of eddies between 5,000 and 25,000 cfs stage, by reach.

CMIN 8.3.1 – Track, as appropriate, the biennial or annual sandbar area, volume and grain-size changes within eddies below 5,000 cfs stage, by reach.

During FY2009, the SED TREND monitoring will address this unranked Goal 8 CMINs.

CMIN 8.6.1 – Track, as appropriate, changes in coarse sediment (> 2 mm) abundance and distribution.

The SED TREND monitoring also directly addresses this top-ranked Goal 9 CMIN priority (covered under project REC 9.R1.08: Sandbar and Campable Area Monitoring under Goal 9**)**.

CMIN 9.3.1 – Determine and track the size frequency, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons. **#1 ranked Goal 9 CMIN**

Developing and testing monitoring protocols for these CMINs was the primary focus of research and development conducted during FY 1998-2006, as reviewed by SEDS-PEP III.

General Methods

During FY08, monitoring under the SED TREND monitoring will focus on Task 3 described above. Task 3 is conducted using standard ground-based surveying protocols and multibeam-sonar bathymetric surveying protocols (including error analyses) described in Kaplinski and others (2000, 2007, in review). The grain-size data collected under task 3 (recommended by the final PEP panel, Wohl and others, 2006) are collected and processed using protocols described in Rubin and others (2006, in press) and Rubin (2004).

Products/Reports

The expected products and reports associated with the SED TREND monitoring are summarized as follows:

- Annual updates of the NAU sandbar time series showing trends in the area and volume of the high-elevation parts of sandbars. In addition to providing annual data showing the effectiveness of dam operations on rebuilding and maintaining sandbars **(covered under project REC 9.R1.08: Sandbar and Campable Area Monitoring under goal 9).** (By end of calendar year – December 31, 2009).

- Topographic maps of the CRE in the first of five long reaches: upper Marble Canyon, lower Marble Canyon, eastern Grand Canyon, central Grand Canyon, and western Grand Canyon. **During FY08, monitoring will focus on upper Marble Canyon.** These maps will be produced 1-2 times per decade for each reach on average. These maps will characterize the geometries of the backwaters (thought to be important habitat for native fish) in each ~30-mile reach. (By end of calendar year – December 31, 2009).

- Mapping conducted during FY08 will ultimately result in decadal timescale sediment budgets for these five reaches of the CRE. These data will provide managers information on the long-term status of the fine-sediment "bank account." These sediment budgets will be compared to the sediment budgets computed for these reaches under the complimentary mass balance project described under Goal 7. This comparison will help evaluate the uncertainties associated with the SED TREND monitoring and mass balance approaches. (By end of calendar year – December 31, 2009).

- Where possible, data collected in Upper Marble Canyon in FY08 will be compared with earlier multi-beam-sonar data collected in 2000, 2001 and as part of the 2002–04 FIST project to evaluate volume changes in the fine-sediment bank account (2000 vs. 2008). (By end of calendar year – December 31, 2009).

- Annual peer-reviewed USGS data reports documenting results of the monitoring project. Contribution to other research-related peer-reviewed publications (such as models). Bi-annual presentations at GCDAMP meetings and GCMRC Science Symposiums. (By end of calendar year – December 31, 2009).

Budget

PHY 8.M1.08	
Core Monitoring (Task #3) of Fine Sediment (FY08–FY11) "SED TRENDS"	
	Fiscal Year 2008

GCDAMP Goal 9: Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.

REC 9.R1.08/PHYS 8.M2.08: Sandbar and Campable Area Monitoring

Start Date

October 2007 (This monitoring project is a continuation of monitoring efforts that have been occurring annually since 1990 for sandbar area and volume and since 1998 for campable area.)

End Date

Ongoing

Principal Investigator(s)

R. Parnell, M. Kaplinski, and J. Hazel, Northern Arizona University, Geology Department, Flagstaff, Ariz., in cooperation with GCMRC staff scientists

Geographic Scope

Sandbar and campable area monitoring has historically focused on 45 sandbars along the main channel of the Colorado River between Glen Canyon Dam (GCD; mile -15) and Diamond Creek (mile 226). However, about five additional sites are being proposed for inclusion in this monitoring project below river mile 225, downstream to the western boundary of the geographical scope of the GCDAMP program (approximately river mile 278). The reach below Diamond Creek has been of increasing interest to managers due to the persistent period of lower reservoir elevations and storage in Lake Mead, and large sandbars that are now exposed along a flowing river reach. This western-most reach of the study area is frequently used for recreational camping and boating, and additional biological studies are also underway below Diamond Creek (fishery monitoring, etc.).

Project Goals/Tasks

The goal of this project is to track change in sandbar volumes and topography and link these data to changes in campable area using established monitoring protocols while alternative monitoring approaches using remotely sensed data are being explored and tested. The specific objectives of this study include (1) annually measuring sandbar area, volume, and campsite area at a series of long-term monitoring sandbar sites, (2) evaluating changes in campsite area in relation to bar volume and topography, and (3) evaluating changes in campsite area in relation to past monitoring results at different flow stages.

Need for Project

Public concern with the ongoing loss of sandbar "beaches" and recreational capacity in the Colorado River corridor was a key factor leading to the development of the 1995 Glen Canyon Dam Final Environmental Impact Statement and passage of the Grand Canyon Protection Act (GCPA) in 1992. The protection of visitor use values is specifically identified as a goal of GCPA. This project directly addresses one part of the top priority core monitoring information need (change in campsite size) for goal 9 of the GCDAMP Strategic Plan.

This project will also provide data to managers about the status and trend of sandbars throughout the Colorado River ecosystem (CRE) below GCD that have been monitored annually since 1990. Sandbar measurements (area and volume relative to stage elevations) at these long-term monitoring sites has been reported annually to the GCD AMWG since its formation in 1997, and was also presented to managers annually during the GCES II era of the EIS. The Strategic Plan of the GCDAMP AMWG identifies conservation of fine sediment as a desired program outcome (GCAMP goal 8). Recently the GCDAMP (August 2004) identified sediment resources as the program's 4th priority area of concern and interest, as articulated in the following question:

- GCDAMP Priority 4: What is the impact of sediment loss and what should we do about it?

Strategic Science Questions

There is still uncertainty about the future fate of sandbars below GCD under proposed operational strategies intended to promote sand conservation of tributary inputs. The supply of new sand below the dam is estimated to be about 6% of the predam supply in Marble Canyon and about 16% of the predam supply below the confluence with the LCR (river miles 61–278). The Northern Arizona University (NAU) sandbar monitoring data is extremely useful in addressing specific strategic science questions and evaluating the Record of Decision (ROD) operations, as well as alternative operations being considered by managers. Monitoring data pertaining to sandbar volume change address the following strategic science question:

> **SSQ 4-1.** Is there a "Flow Only" operation (i.e., a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal time scales?

In terms of questions that are specific to the recreation goal, this project also directly addresses the following strategic science question:

> **SSQ 3-9.** How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

Because campsite size, distribution, and physical attributes are known to affect visitor experience, this project also indirectly addresses two other important science questions related to recreation in the CRE:

> **SSQ 3-7.** How do dam controlled flows affect visitors' recreational experiences, and what is/are the optimal flows for maintaining a high quality recreational experience in the CRE?

> **SSQ 3-8.** What are the drivers for recreational experiences in the CRE, and how important are flows relative to other drivers in shaping recreational experience outcomes?

Links/Relationships to Other Projects

This monitoring project incorporates the long-term NAU sandbar survey project that has been underway since the early 1990s and the associated campable area surveys that have occurred annually at a sub-set of these sandbars since 1998. Although formerly distinguished as separate monitoring projects, one directed at Goal 8 and the other at Goal 9, both the NAU sandbar survey and campable area monitoring projects are concerned with monitoring sandbar sediment, albeit in different respects. The NAU sandbar survey tracks changes in total area and volume of the sandbars above the 5,000 cfs level, while the campable area monitoring project specifically evaluates changes in campable area at a sub-set of these sandbar sites. In combination, these two projects provide a holistic assessment of how flows are affecting the sandbar habitats used by recreational boaters for camping.

Campsite Inventory and GIS Atlas

The assessments of campable area throughout the river ecosystem will be evaluated as a subset of sites included in the campsite inventory. Data resulting from this monitoring project will be incorporated into the GIS campsite atlas that is under development in FY07–FY08 (REC 9.R3.08).

In addition to recreation resources, sandbars are closely linked with other resources of GCDAMP concern, such as terrestrial and aquatic habitats related to native fish rearing areas (backwaters) and cultural site preservation, as discussed in more detail below.

Changes in Nearshore Habitats (shoreline types and abundance of backwaters)

At those study sites with well-defined return-current channels, topographic measurements made at the long-term sandbar monitoring sites also incorporate the morphology and size of backwaters. Three-dimensional topography data can therefore be used to analyze local river stage versus depth and area relationships for backwaters at these monitoring sites as one means of addressing what operational ranges of flow are most conducive to backwater size and stability. The sandbar and campable area data will be incorporated into the shoreline habitat study planned for FY07–FY08 (DASA 12.D6.08).

Archaeological Sites

Generally, sandbar monitoring tracks changes in higher-elevation sand areas and volumes at a sub-sample of sites throughout the system. The abundance of sand above the active fluctuating-flow operating zone (above 25,000 cfs stage) provides information about whether sand storage in those areas is stable, increasing or decreasing through time in response to normal operations or experimental high-flows intended to promote conservation of new sand supplies. The abundance of sand along shorelines that is available for transport by wind to higher elevations where archaeological preservation sites are located is thought to be related to the potential for eroded sites to be reburied by new sand. In the future, additional process studies at such cultural sites may be tied more directly to sandbar monitoring at existing sites, as well as by adding additional monitoring sites over time that are proximal to cultural research sites.

Information Needs Addressed

Sandbar monitoring above the 5,000 cfs level directly address information needs specified within the “Fine-Sediment” section (GCDAMP goal 8) of the GCDAMP Strategic Plan:

> **CMIN 8.2.1.** Track, as appropriate, the biennial sandbar area, volume and grain-size changes outside of eddies between 5,000 and 25,000 cfs stage, by reach.
>
> **CMIN 8.5.1.** Track, as appropriate, the biennial sandbar area, volume, and grain-size changes above 25,000 cfs stage, by reach.

This project also directly addresses one part of the top priority CMIN for goal 9 (campsite size):

> **CMIN 9.3.1.** Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons. (This project specifically addresses the part of the CMIN concerned with campsite size.)

This project partially addresses a second campsite CMIN (9.3.2) that is very closely related to the first priority CMIN for camping beaches:

> **CMIN 9.3.2.** Determine and track the effects of ROD operations on the size, quality, and distribution of camping beaches in the CRE.

This monitoring project will also contribute to tracking one outcome of experimental flows on camping beaches (campable area), as defined by EIN 9.3.1.

> **EIN 9.3.1.** How do the size, quality, and distribution of camping beaches change in response to an experiment performed under the ROD, unanticipated event, or other management action?

General Methods

Repeat surveys of long-term sandbar monitoring sites have been conducted since 1990 using trained field personnel under the joint direction of the GCMRC's survey department staff and scientists from NAU, Department of Geology. Campable area survey protocols have been established and applied consistently by the same team of scientists since the late 1990s (Kaplinski and others, 2005). As described in the State of the Colorado River ecosystem in Grand Canyon report (Kaplinski and others, 2005:196), campable area surveys are conducted annually in the fall, at the conclusion of the prime river recreation season. Survey crews from NAU Department of Geology survey selected study sites using standard total station survey techniques (USACOE, 1994). Topographic data are collected and referenced to AZ State-Plane Coordinates generated through the GCMRC's survey control network activities throughout the CRE. Data are reduced and analyzed by the NAU team in cooperation with GCMRC partners and presented in a variety of formats, but most typically are reported as cumulative area and volume totals. The volumes and areas are also assessed relative to flow and stage elevations linked to dam operations. While methods for surveying "off-shore" topography within eddies below the 5,000 cfs stage are being evaluated by external peer reviewers in FY06–FY07, monitoring data will continue to be collected in shallower portions of the eddies and in the terrestrial portions of the sandbars using the established conventional, ground-survey methods. Once the protocol for measuring sandbar topography in deeper, off-shore areas is resolved, then information relating to CMIN 8.1.1 shall be collected at these sites (presumably starting in FY09).

Surveyors follow the criteria of Kearsley (1995) and Kearsley and Quartaroli (1997) to identify campable area. Campable area is defined as "a smooth substrate (preferably sand) with no more than eight degrees of slope with little or no vegetation" (Kaplinski and others, 2005:196.) Although the goal is to capture the total campable area at each site, camping areas located at considerable distance (>100 m) from the main mooring/cooking areas are generally not included in the totals. In the future, these protocols may be adjusted to measure all campable area with variable slope criteria within the National Park Service (NPS) -defined campsite boundaries using remotely

sensed data (see research project description 9.R2.08 in the FY07 work plan); however, until new protocols are tested and refined, the existing monitoring program will continue.

Products/Reports

The following products/reports are expected to be produced on an annual basis:

- Annual Report - documenting the change in sandbar topography, volume, area, and campable area and summarizing implications for fine sediment storage data throughout the main channel. These data will also be served through the GCMRC Web page.
- Biennial GCMRC Science Symposium abstract and presentation.

Budget

REC 9.R1.08	
Sandbar and Campable Area Monitoring (FY07–FY11)	
	Fiscal Year 2008

REC 9.R3.08: Compile Campsite Inventory and GIS Atlas (Year 2)

Start Date

October 2006

End Date

September 2008

Principal Investigator(s)

This project will be jointly funded and jointly implemented by staff from Grand Canyon National Park and GCMRC.

Co-principal Investigator, GRCA: Linda Jalbert, Outdoor Recreation Planner.
Co-principal Investigator, GCMRC: Helen Fairley, Sociocultural Program Manager.

Geographic Scope

Entire Colorado River ecosystem (CRE), from base of Glen Canyon Dam (GCD) to Lake Mead (Mile 277).

Project Goals/Tasks

The goal of this project is to compile a comprehensive current inventory of campsites in the CRE and document the spatial extent, geographic distribution, and associated attributes of these campsites in a GIS atlas. The atlas will document attributes of current campsites that are important to recreation experience and that have the potential to be affected by flows (e.g., campable area, amount of open sand area, type and amount of vegetation cover, and mooring characteristics under varying flows.) The atlas will also document locations and attributes of past campsites that have disappeared due to loss of sediment and/or vegetation encroachment. The atlas will serve as an electronic repository for all data (e.g., repeat photographs, campable area survey data, vegetation transect data, etc.) that has been collected for each campsite over the past few decades.

This inventory and atlas will serve as the baseline for future monitoring and research projects. It will define the boundaries of current campsites in a GIS environment so that future evaluations that rely on remotely sensed data and statistical samples to quantify change in campsite attributes relative to dam operations have a common spatial basis for evaluating change through time. The atlas will have broad utility for both National Park Service (NPS) recreation managers (e.g., Colorado River Management Plan [CRMP] monitoring), as well as for monitoring effects of dam operations on campsites.

Need for Project

Baseline inventories provide the foundation for long-term monitoring programs and research studies. Comprehensive campsite inventories in the CRE conducted initially in 1973 were repeated in1984 (Weeden and others, 1975; Brian and Thomas, 1984). The last comprehensive campsite inventory was completed 15 years ago

in 1991 (Kearsley and Warren, 1993). The 1991 inventory showed a dramatic decline in number and size of campsites compared with previous inventories (Kaplinski and others, 2003). A new comprehensive inventory is needed (Kaplinski and others 2003, 2005; Loomis and others, 2005) to document the current number, size, and distribution of campsites throughout the CRE and to document the boundaries of the areas that NPS proposes to manage as campsites in the future. This database will serve as a baseline and will document the total pool of sites that will be sampled for various research and monitoring projects in the future. This atlas will also serve as the central repository for all campsite data collected during future inventory and monitoring projects. The 2005 recreation PEP identified this as the highest priority research need under management objective 9.3.

Strategic Science Questions

This project directly addresses the following strategic science question:

> **SSQ 3-9.** How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

Indirectly, this project will also provide information that is relevant for addressing a second strategic science question about the effects of flows on the quality of recreational experience in the CRE:

> **SSQ 3-8.** What are the drivers for recreational experiences in the CRE, and how important are flows relative to other drivers in shaping recreational experience outcomes?

Links/Relationships to Other Projects

This project is being undertaken in cooperation with staff from Grand Canyon National Park. In addition to meeting GCDAMP needs, data from this project will be used by the National Park Service as they develop implementation plans and resource monitoring projects tied to the Colorado River Management Plan. Because the NPS has immediate need for some campsite data, $40,000 in equipment and NPS staff salaries is being contributed by NPS in FY06 to initiate the project.

The GIS atlas will serve as the definitive source for information on prior and current campsite inventory data. It will provide a foundation and repository for all future research and monitoring projects related to CRE campsites. In addition to documenting the areas used for recreational camping, the GIS campsite layer will document areas of the CRE most heavily impacted by humans. This information will be useful for assessing human impacts rates on near by cultural resources such as archaeological sites and traditional cultural properties (TCPs).

Information Needs Addressed

This project will lay the foundation for future research and monitoring efforts that are designed to address management objective 9.3 and the top priority CMIN for goal 9:

> **CMIN 9.3.1.** Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons.

CMIN 9.3.1 is very closely related to a second MIN under M.O. 9.3

> **CMIN 9.3.2.** Determine and track the effects of ROD operations on the size, quality, and distribution of camping beaches in the CRE.

The current recreation monitoring program is only focused on one aspect of CMIN 9.3.1: campsite size. This project will allow for the tracking of the other key relevant campsite variables, e.g., campsite distribution and quality. This project will also have utility for monitoring effects of experimental flows on camping beaches (campable area), as defined by EIN 9.3.1.

> **EIN 9.3.1.** How do the size, quality, and distribution of camping beaches change in response to an experiment performed under the ROD, unanticipated event, or other management action?

General Methods

- Using existing published sources (e.g., Stevens, 1992; Martin and Whitis, 2004) and the knowledge of experienced river guides, we will identify and map all currently used campsites in the CRE. (NPS task)
- Using existing sources and the knowledge of experienced river guides, the campsite boundaries (as defined by NPS managers) will be documented in a GIS environment. (NPS task)
- Campsite boundaries will be field checked and verified. (NPS/GCMRC)
- Campsite attributes that are important to visitor experience (substrate characteristics, mooring characteristics, protection from prevailing winds, proximity to attraction sites) will be identified and documented. (GCMRC/NPS)
- Using published information from prior inventories (e.g., Weeden, 1975; Brian and Thomas, 1984; Kearsley and Warren, 1993) all former campsite locations and associated information will be identified and integrated into the GIS atlas. (GCMRC/NPS)
- Supporting documents and photos will be scanned and linked to GIS/spatial data (document legacy metadata). (NPS/GCMRC)
- Using established slope/area/attribute criteria, current campable areas within the campsite boundaries will be classified to assess current carrying capacity. (NPS/GCMRC)

Products/Reports

A comprehensive inventory of campsites and associated legacy data will be documented and published in an electronic GIS atlas as the final product of this project.

Budget (for Year 2 of the 2-Year Project)

REC 9.R3.08	
Compile Campsite Inventory and GIS Atlas (FY07–FY08)	
	Fiscal Year 2008

*In FY06, NPS contributed $40,000 in staff salary, equipment purchases, and supplies in order to get this project started. In FY07, NPS contributed approximately $60,000 in staff salaries, equipment purchases, logistics an supplies. These NPS contributions are NOT reflected in the budget shown above.

GCDAMP Goal 10: Maintain power production capacity and energy generation, and increase where feasible and advisable, within the framework of the Adaptive Management ecosystem goals.

HYD 10.M1.08: Monitor Power Generation and Market Values under Current and Future Dam Operations

Start Date

October, 2006

End Date

Ongoing

Principal Investigator(s)

Data will be provided by Western Area Power Administration (WAPA) and distributed via the GCMRC Web site.

Geographic Scope

Hydropower generation data and market values for the energy generated by Glen Canyon Dam (GCD).

Project Goals/Tasks

The goal of this core monitoring project is to monitor and document hourly hydropower generation and potential opportunity (replacement) costs under current and future flow regimes.

Need for Project

Power generated at GCD is marketed mostly in six western states by the Department of Energy's Western Area Power Administration. WAPA's primary mission is to sell power from Federal water project power plants under statutory criteria in the Reclamation Project Act of 1939, the Flood Control Act of 1944, and the Colorado River Storage Project Act of 1956. These criteria include:

- Preference in the sale of power must go to municipalities, public corporations, cooperatives, and other nonprofit organizations.
- Power must be marketed at the lowest possible rates consistent with sound business practices.
- Revenues generated from power sales must pay for power generation and all allocated investment costs under the original Colorado River Storage Project (CRSP) Act.

- Projects should generate the greatest amount of power and energy that can be sold at firm power and energy rates, consistent with other project purposes.

Tracking generation (as impacted by operations for other project purposes) power market rates, necessary power purchases, and Basin Fund cash flow provides the means to assess the impact of changes in GCD operations in relation to the four statutory criteria.

Currently, there are no ongoing core monitoring activities related to goal 10. Although data on GCD hydropower generation and opportunity costs under modified low fluctuating flow (MLFF) operations are currently being gathered by Bureau of Reclamation (Reclamation) and WAPA as routine agency functions, these data are not readily accessible to the GCDAMP. The need for this information in a readily accessible format has been identified as a program need, and this project will help to fill this critical information gap.

Strategic Science Questions

SSQ 3-3. What are the annual hydropower replacement costs of the MLFF since 1996?

SSQ 3-4. What are the projected hydropower costs associated with the various alternative flow regimes being discussed for future experimental science (as defined in the next phase experimental design).

Links/Relationships to Other Projects

This project is directly linked to the newly proposed adaptive management assessment initiative proposed for goal 12. It also is specifically related to the current overall long term planning needs of the GCDAMP.

Information Needs Addressed

This project responds to the core monitoring information need for goal 10, as originally articulated in the 2003 version of the GCDAMP Strategic Plan, and redefined by the Science Planning Group (SPG):

IN 10.1. Determine and track the impacts to power users from implementation of ROD dam operations and segregate those effects from other causes such as changes in the power market.

CMIN 10.1.1 (as redefined by SPG). Determine and track the marketable capacity and energy produced through dam operations in relation to the various release scenarios (hourly/daily/monthly volumes, daily fluctuation limit, upramp and downramp rates and limits, etc.).

General Methods

WAPA and Reclamation continuously schedule and monitor power generation to meet anticipated and real-time power demand. This information is available on an hourly time-step reported daily, weekly, and monthly from SCADA data. WAPA and its customers track power source, availability, and market changes on an hourly basis in assessing the need, cost, and accessibility for additional power resources to meet contractual obligations or unanticipated demand. Market pricing, resulting cost of purchases and the impact on Basin Fund cash flow are recorded in the WAPA Energy Tracking Database (ISA). This information is reported monthly and annually, and available through WAPA-CRSP, but not publicly published. Figure 2.5 summarizes the metrics and frequency of data collection for power costs.

Figure 2.5. Metrics and frequency of data collection for power costs.

Objective	Parameters	Methods	Location(s)	Frequency	Accuracy & Precision
Monitor monthly energy generation	MW	SCADA	SCADA Phoenix – Dumped Energy Management System (ISA)	Hourly	N/A
Monitor hourly power market price	$/MWH	WAPA Energy Tracking Database (ISA)	WAPA - Montrose	Hourly	N/A
Monitor monthly firming power purchases	$ and MW purchased	WAPA Energy Tracking Database (ISA)	WAPA - Montrose	Monthly	N/A
Monitor monthly Basin Fund Balance	$	WAPA Energy Tracking Database (ISA)	WAPA - CRSP	Monthly	N/A

Energy Generated: The SCADA system that measures generation at GCD is reported to a database that is accessible by the WAPA Phoenix office. Currently, those data are dumped into the CRSP-Montrose office ISA, and from ISA monthly generation is calculated by summing all the hourly values. Hourly generation totals are not currently reported but can be accessed by WAPA-CRSP or WAPA-Montrose. For the purposes of this project, hourly data will be reported.

Hourly Market Prices: Market prices vary at different purchase points throughout the system. The price that WAPA-Montrose pays for power is pertinent to WAPA and its customers. This value is available only for the hours in which WAPA buys or sells power; therefore, the data set is incomplete. If complete data is needed by WAPA-Montrose, they may look at the Dow Jones for a representative point of sale and record that data price. These data can be accessed via the Web and reported to an Excel spreadsheet if access is requested and granted by WAPA-Montrose.

Basin Fund Balance: The financial manager for the CRSP office completes an end-of-month cash balance and Basin Fund balance report found on WAPA's Web site. The reports are usually completed by the 15th of the month. These data will be for the previous month's billing on the 2 months previous services. These reports are found at **www.wapa.gov/crsp/L8000doc/CRSP%20Cash%20Status%200205.pdf** and **www.wapa.gov/crsp/L8000doc/CRSP%20Basin%20Fund%20Cash%20(Graph)%200205.pdf.**

Monthly Firming Purchases: These data is found in the WAPA-Montrose TDB database. Purchases made by WAPA for customers are reported by the 10th of the following month, broken out by customer (purchased from). This report is sent to WAPA and can be made available.

Products/Reports

Hourly data will be collected by WAPA and delivered to GCMRC on a daily basis. These data will be served through the GCMRC Web site. Monthly data will be delivered to GCMRC at the conclusion of each month.

Budget

HYD 10.M1.08	
Monitor Power Generation and Market Values under Current and Future Dam Operations (FY07–Ongoing)	
	Fiscal Year 2008

* GCMRC salaries are for setting up Web site and connections to receive and deliver the data.

GCDAMP Goal 11: Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations.

CUL 11.R1.08: Research and Development Towards Core Monitoring, Phase II.

Start Date

October 2007

End Date

September 2010

Principal Investigator(s)

Individual tasks will be accomplished using a combination of GCMRC personnel and outside contractors and/or cooperators. It is anticipated that the National Park Service (NPS) will assist with the pilot monitoring efforts; other components will involve a combination of university cooperators, U.S. Geological Survey (USGS) researchers, and independent contractors.

Geographic Scope

Colorado River ecosystem (CRE) as defined in the GCDAMP Strategic Plan

Project Goals/Tasks

This cultural monitoring project is part of a phased program of research and development towards implementation of a long-term core monitoring program. The first phase of this project (FY06–FY07) focused on conducting research and development (R&D) for refinement of monitoring protocols. More specifically, the focus of the first 2 years of this project was on completing a comprehensive assessment of the geomorphoric and archaeological attributes of sites to aid in the development of the long term monitoring approach and testing field protocols to be included in a long-term, core monitoring program for archaeological resources in the CRE.

FY08 will be the first year of a three monitoring cycle employing the refined protocols developed during the preceding R&D phase. In FY08 we will continue to build on several R&D activities initiated in FY06, including: 1) continuing to gather data on several short-term, small-scale studies to evaluate the effectiveness, efficiency, and accuracy of various field measurement techniques before implementing them as part of a long-term monitoring program (including weather monitoring, LIDAR mapping, and thalweg survey measurements at a subset of sites)., 2) continuing to monitor check dam effectiveness at a subset of sites and expanding this monitoring to additional sites in the CRE, and 3) applying the preliminary results from the first 2 years of the R&D work toward defining and implementing a pilot monitoring project for the next 3 years. The ultimate

outcome of this R&D effort will be a final report with specific monitoring protocol recommendations. The program will ultimately be subject to a final review by a protocol evaluation panel (PEP) in late FY10 or early in FY11, with additional refinement of protocols (if necessary), before being implemented as the long-term program.

The scope of this project encompasses the full range of archaeological resources in the Colorado River corridor during the time of human occupation. The actual number of archaeological sites that will be included in the pilot monitoring program will be determined upon completion of the assessment phase of this project.

This project does not address R&D for monitoring of tribally valued resources other than archaeological sites, because in FY06–FY07, the six affiliated tribes participating in the GCDAMP are be reviewing and defining their monitoring data needs, with the aim of ensuring that the values of importance to each tribe are clearly identified and addressed in future tribal and non-tribal monitoring efforts. This initial phase of tribal monitoring program definition is underway through sole source contracts between Reclamation and the tribes. Integration of these planning efforts into the core monitoring program will depend on the focus of monitoring projects proposed by the tribes, and will be accomplished after completing the initial research and development phase of these projects, during implementation of the pilot monitoring phase.

Need for Project

The FY00 cultural PEP recommended redesigning the 1999–2000 programmatic agreement monitoring program to focus more specifically on tracking effects of dam operations and evaluating the efficacy of erosion control efforts (Doelle, 2000). Subsequently, the Science Planning Group (SPG) and Cultural Resources Ad Hoc Group (CRAHG) redefined the primary core monitoring need for historic properties to track status and trends of site condition and integrity through monitoring rates of erosion, visitor impacts, and other variables or processes known to affect archaeological site condition. This project will explore and test various options for measuring change and achieving these defined monitoring objectives, before implementing a long-term core monitoring program.

Grand Canyon is one of the classic erosional landscapes of the world, and to some degree erosion of unconsolidated deposits along the Colorado River corridor is inevitable. Yet many cultural resources are being damaged by rapid gully erosion, and recent studies have shown that erosion of the sediment that forms the context of cultural sites has increased in the past few decades (Hereford and others, 1993). Previous research raised several basic questions that are ongoing issues in the river corridor: 1) what are the geomorphic controls and other environmental factors contributing to gully erosion, and what are the ultimate causes of this gully erosion; 2) what is the effectiveness of installed erosion-control measures; and 3) are there accurate, low impact, and cost-efficient monitoring methods that can replace the qualitative assessments and high-impact ground surveys used in the past? Results of recent research by Pederson and others, (2003) indicate that the exploration of remote sensing options for monitoring could potentially be redirected from photogrammetry to high intensity LiDAR. Also, erosion-control efforts—brush check dams in particular—appear to be effective at slowing erosion, but results thus far are from a single-year study, and a longer-term assessment is needed to help narrow the focus of future post-treatment monitoring approaches.

Monitoring of the deposition and erosion of sediment at archaeological sites along the Colorado River corridor in Grand Canyon has been done mostly through qualitative observation documented with repeat photography. This approach has been supplemented by total-station ground surveys at a select number of sites in the river corridor. Although the total station survey method is highly accurate and precise, it is labor intensive and expensive for long-term, frequent monitoring of multiple sites. Perhaps more importantly for cultural resource management, intensive survey monitoring has its own erosional impacts through significant trampling of crytobiotic crusts and

trailing. Research findings by Pederson and others (2003) showed that erosion is primarily focused at knickpoints and channel heads, and it also indicated that monitoring could be effective with a relatively limited analysis of thalweg and channel cross-section profiles rather than full terrain total station surveys. These preliminary findings will be tested and evaluated as part of this research effort towards establishing long-term monitoring protocols for archaeological sites.

Since conclusion of the Pederson study, GCMRC has tested light detection and ranging (LiDAR) survey technology for tracking sandbar changes along the Colorado River corridor. This state-of-art technology has potential advantages over photogrammetry or total station surveys of topography by being significantly less labor-intensive to produce, having lower technician error or bias, and lower overall impacts to the terrain. Initial indications are that the accuracy of LiDAR data in this setting is at least as good as that of the photogrammetry reported in Pederson and others (2003) (Mike Breedlove, pers comm), but this technology has not been tested for its utility in tracking gully erosion, nor has its repeat accuracy been rigorously determined. Although traditional ground-survey will be employed in this project, alternative remote-sensing methods for monitoring treatment effectiveness (and erosion) at archaeological sites in the future will also be explored.

Strategic Science Questions

SSQ 2-1. Do dam controlled flows affect (increase or decrease) rates of erosion, and vegetation growth, at archaeological sites and TCP sites in the CRE, and if so, how?

SSQ 2-4. How effective are various treatments (e.g., check dams, vegetation management, etc.) in slowing rates of erosion at archaeological sites over the long term?

Links/Relationships to Other Projects

This project is linked to the treatment planning effort that was initiated by the Bureau of Reclamation (Reclamation) in FY06. Specifically, it will extend the site assessment process initiated for treatment planning purposes to include assessments of sites that appear to be stable at this time, but that could be affected by the propagating effects of dam operations in the future. It will also build upon a pilot research project conducted by Utah State University (USU) in FY06 to assess effectiveness of check dams; this will be accomplished by formalizing and extending the USU study for a second year to assess the utility of monitoring geomorphic change using similar measurement protocols as those being piloted in the FY06 study.

As noted above, opportunities for integrating the results of this R&D effort with those of the tribal monitoring projects will be explored after completing the initial research and development phase of these projects. This delay in integration is necessary in order for the needs and approaches of the tribal monitoring programs and the Federal agencies to be articulated and appropriate protocols identified. Integration of monitoring efforts, as appropriate, will occur during implementation of the pilot monitoring phase (FY08–FY10).

This project builds upon the work of Draut and Rubin (2005, 2006) by incorporating weather monitoring at a small number of sites on a pilot basis as one of the long-term monitoring protocols to be evaluated. This study is also linked to the National Park Service's Colorado River Management Plan (CRMP) implementation efforts, in that monitoring protocols for assessing impacts of human visitation at archaeological sites are being developed cooperatively with NPS to serve the monitoring data needs of both GCDAMP and the CRMP.

Information Needs Addressed

This project is an R&D effort aimed at addressing the highest priority CMIN for historic properties (as revised by the Cultural Resources Ad Hoc Group and SPG in fall of 2005), specifically the properties known as archaeological sites:

> **CMIN 11.1.1 (SPG revised).** Determine the condition and integrity of prehistoric and historic sites in the CRE through tracking rates of erosion, visitor impacts, and other relevant variables. Determine the condition and integrity of TCPs in the CRE.

It will also directly address CMIN 11.1.2 of the GCDAMP Strategic Plan (renumbered by CRAHG/SPG as EIN 11.1).

> **EIN 11.1.** Determine the efficacy of treatments for mitigation of adverse effects to historic properties.

This project also addresses a research information need (formerly identified as CMIN 11.1.4 in the GCDAMP Strategic Plan):

> How effective is monitoring, what are the appropriate strategies to capture change at an archaeological site – qualitative, quantitative?

General Methods

Task 1. Analyze the Assessment Data Collected in FY06-07 and Cluster Data based on Geomorphic Characteristics and Archaeological Attributes and Values

The assessment of archaeological sites for the development of the long-term monitoring program began in FY06. Work has consisted of assembling, evaluating, and verifying legacy information (NPS monitoring data) regarding the archaeological resources and updating the information where warranted. In FY06, this work was coordinated with the site-specific assessments being conducted by USU geomorphologists, Dr. Joel Pederson and Mr. Gary O'Brien, and Dr. Jonathan Damp from Zuni Cultural Resources Enterprise (ZCRE) for the Reclamation's Section 106 Grand Canyon treatment plan development. In FY07, assessment work continued at the remaining sites not proposed for inclusion in the treatment plan. The goal of the assessment phase was to ensure that accurate, up-to-date, and comparable levels of information existed for all of the potentially monitored archaeological sites. Uniform baseline data is critical for selecting a statistically valid sample of the sites to be used in the long-term core monitoring program.

Variables assessed for each site included the attributes and characteristics that contribute to site significance (elements of integrity as reflected in nature of artifact assemblage, numbers and types of constructed features, presence and extent of subsurface cultural deposits, specific research values, and association with historical events or people.) A concurrent assessment process evaluated the geomorphic context and attributes that affect site stability and/or degree of erosion (e.g., topographic setting, gully catchment characteristics, resilience of the substrate to erosion, degree to which individual gullies are integrated with the river.)

In fall 2007, following completion of the final 2007 data collection effort and its integration within a database, the resulting data will be clustered using Gower's coefficient for mixed variables types (Gower, 1971) and Ward's minimum variance clustering algorithm (Ward, 1963), in order to group sites for defining future monitoring protocols that are relevant to particular groups of sites and for stratifying the site population for future sampling

purposes. Clusters will be analyzed in a GIS to detect spatial distributional patterns and potential biases. Samples will then be drawn from each of the clusters for the pilot monitoring effort which is scheduled to commence in spring, 2008. **Sub-task allocation for compiling, exploring and analyzing these data, integrating them with the other data collected under Task 2 (see below), evaluating all data in a GIS environment, and preparing the final pilot monitoring plan is $44,600.**

Task 2. Implement Pilot Monitoring Protocols for Geomorphic Change Detection and Erosion Control Effectiveness Monitoring

In order to test and evaluate quantitative monitoring protocols, approximately six study sites (each study site consisting of two to three archaeological sites located in close proximity to each other) were repeatedly mapped and intensively evaluated in FY06-07. These data are currently (May, 2007) being compiled and analyzed. In FY08, the same study sites evaluated in FY06–FY07, plus approximately six additional locations, will be intensively surveyed to quantify rates of gully erosion and topographic surface change occurring throughout the canyon in a variety of geomorphic settings. Specific study sites will be determined based on the results of the geomorphic assessment analysis that will be completed following the final FY07 field session.

Continue Collecting Field Data on Gully Erosion Rates

Previous research findings by Pederson and others (2003) showed that gully erosion is clearly focused at knickpoints and channel heads, and it also indicated that monitoring could potentially be effective with a relatively limited analysis of thalweg and channel cross-section profiles rather than full terrain surveys. This study is building upon Pederson's prior research for the purpose of testing and evaluating the most appropriate and cost effective methods to measure geomorphic change at archaeological sites and also to evaluate the effectiveness of erosion control devices that may be installed at various sites in the future.

Consistent with previous years, field data collection will occur two times per year, once before the monsoon season and once after the monsoon in the late fall. Basic geomorphic data related to thalweg evolution will be collected, and repeat photographs of check dam and gully features will be taken to track changes coincident with hydrologic events or other disturbances. Data collected will include field observations of piping and overland flow features, integrity of check dams, and evidence of past and recent aeolian activity. The effectiveness of installed check dams will continue to be evaluated by comparison of monitoring data from FY08 to previous thalweg and topographic data collected at the same localities, as well as to unmitigated gullies at nearby sites. Criteria for "being effective" are: 1) whether check dams remain competent and in place; 2) if measurements and/or photographs reveal they successfully trap and store sediment; and 3) if surveys document that channel widening and knickpoint recession are constrained or do not happen at all during runoff events.

Care will be taken to prevent gully wall failure and disturbance around cultural sites during ground surveys, and gully surveys will be limited to the essential data provided by gully thalweg profiles and topography and at select cross-sectional channel profiles at major knickpoints. This will minimize the amount of trampling of study sites by intensive surveys outside of already-disturbed gully channels. **Sub-task allocation for collecting and analyzing gully thalweg measurements and preparing a report on findings is $85,000, not including GCMRC personnel costs. This funding will be provided to USU through a cooperative agreement.**

Continue to Monitor Topographic Change and Establish New Baseline Topographic Records

In FY08, we will continue to develop data pertaining to topographic change at archaeological sites using a combination of conventional total station mapping and ground based high-density LiDAR data at selected study sites. Both LiDAR-produced digital terrain models and ground-survey data will be georeferenced and provided by

GCMRC. Total-station ground surveys will be directed by GCMRC personnel following methods employed by previous GCMRC researchers for capturing topographic changes using high density data collection methods (e.g. Yeatts, 1996; Hazel and others, 2000; Pederson and others, 2003). LiDAR data will be manually edited and filtered to produce a "bare-earth" terrain model without reflections from vegetation canopy. In FY08, approximately six additional sites with high potential for topographic change (based on the geomorphic assessment results) will be added to the sample of sites being monitored in this fashion. **Sub-task budget allocation for LiDAR survey work is $ 70,000, not including GCMRC personnel costs. This funding will be provided to USGS Western Coastal Geology and Marine Division through an internal USGS sub-allotment.**

Weather Monitoring

In FY07, 10 weather stations were established at eight study sites in the CRE. The study sites include the same ones where gully measurements and LiDAR surveys are occurring, plus two additional sites. In FY08-FY10, these stations will continue to monitor precipitation amount and intensity, wind direction and velocity, temperature, humidity, barometric pressure, as well as sediment transport rates. Because of the spatially isolated nature of monsoon thunderstorms and the significant role that precipitation and wind play in down-cutting and backfilling gullies, weather stations and sand traps have been placed in proximity to the study sites where intensive mapping and monitoring of erosion control effectiveness is occurring, so that changes detected from repeat topographic mapping can potentially be related to timing and duration of local or regional weather events.. These stations are outfitted with automated data loggers that can store up to 3 months of data. We are also in the process of exploring telemetry and automated sand traps as a means to facilitate data collection. **Sub-task budget allocation for weather monitoring is $113,000. This includes equipment replacement and technical maintenance, data processing, quality control, and analysis. The equipment maintenance, data collection and processing tasks are being managed internally by GCMRC; data analysis will be handled through an internal USGS sub-allotment to USGS Western Coastal Geology and Marine Division.**

Site Condition Evaluations

Concurrent with the gully thalweg surveys and topographic mapping work, data will be collected on surface indicators of condition using a standardized recording format. These data will document a combination of indicators that reflect both geomorphic and human agents of change affecting site condition in the CRE. The specific recording formats will vary, depending of the type of site being monitored, which be determined from the clustering exercise to be conducted in fall-winter 2007, following completion of the field assessment work in September-October 2007. **Sub-task budget allocation for the condition indicator monitoring task is $70,000, not including GCMRC personnel costs. This amount will be allocated to the National Park Service for participation in the field work activities and compiling data in a database.**

Products/Reports

Several peer-reviewed reports will be prepared at the conclusion of this study. Each report will focus on a specific element/task of the R&D project:

- Report on analysis of FY06-07 assessment data and development of site clusters from the archaeological and geomorphic assessment data.
- Sample selection for the pilot monitoring project.
- LiDAR maps and gully thalweg measurements from sites surveyed in FY06–FY07 and preliminary survey data from FY08

- Summary of first year pilot project monitoring results (winter 2009)

Budget

CUL 11.R1.08	
Research & Development toward Core Monitoring (FY08)	
	Fiscal Year 2008

CUL 11.R2.08: Implement Tribal Monitoring Projects

Start Date

TBD, following TWG approval of the individual tribal monitoring plans

End Date

September 2008

Principal Investigator(s)

TBD by each tribe

Geographic Scope

Colorado River ecosystem (CRE)

Project Goals/Tasks

The goal of this project is to collect data on tribally valued resources, including culturally valued elements of the terrestrial ecosystem and traditional cultural properties (TCPs), and evaluate their condition in concordance with the individual tribe's perspectives and value systems.

Need for Project

Tribal stakeholders (i.e., the Hopi Tribe, Hualapai Nation, Kaibab Band of Paiute Indians, Navajo Nation, Paiute Tribe of Utah, and Pueblo of Zuni) have expressed interest in participating in the evaluation of CRE resources in a manner consistent with tribal concerns and value systems. The tribal stakeholders maintain that current monitoring approaches based exclusively on western science paradigms do not adequately capture tribal interests or concerns. In response to these issues, in FY06 the GCDAMP funded the tribes to articulate their concerns more explicitly, design monitoring approaches that will more fully meet their needs, and bring their proposed monitoring programs forward to TWG for GCDAMP consideration and formal approval. This FY08 project has been funded at the request of the TWG, subject to the stipulation that the tribes first complete their current contractual agreements with Bureau of Reclamation (Reclamation) to develop and report on their proposed monitoring programs and present them to TWG for formal approval.

Strategic Science Questions

This project directly addresses the following strategic science question:

> **SSQ 2-7.** Are dam controlled flows affecting TCPs and other tribally valued resources in the CRE, and if so, in what respects are they being affected, and are those effects considered positive or negative by the tribes who value these resources?

Links/Relationships to Other Projects

The tribes' interests in the CRE are broad, encompassing both cultural-historical sites and biological elements. Many archaeological sites in the CRE are also traditional cultural properties (TCPs) for individual tribes. Thus, the monitoring program for archaeological sites, which is driven in large measure by Western science interests in historical information preservation, overlaps with the interests of tribes, who share a concern for retaining these cultural landmarks for a variety of different reasons. The archaeological site monitoring project and tribally monitoring projects are currently being developed separately but on parallel tracks with the understanding that once areas of mutual concern have been identified, we will seek ways to reduce monitoring cost and field effort and improve efficiencies for all programs by combining monitoring efforts where feasible.

The tribes also have a long-standing interest in the condition of traditionally valued plants and animal resources. These interests are often place-specific, in that the cultural value of biological resources may be enhanced by their association with TCPs. In FY08, the tribes will be asked to participate in the terrestrial ecosystem PEP and provide an overview of their monitoring approaches and existing terrestrial ecosystem monitoring (TEM) -related data for potential incorporation into long-term TEM protocols. Again, the concept is to identify areas of mutual interest between western scientific approaches and tribal concerns, so that opportunities for reducing monitoring costs and improving program efficiency can be identified, while at the same time, ensuring that information relevant to tribal interests are obtained as part of the long-term core monitoring program.

Information Needs Addressed

This project is directly responsive to the highest priority core monitoring information need for cultural resources, as revised by the Cultural Resource Ad Hoc Group and the SPG

> **CMIN 11.1.1.** Determine the condition and integrity of prehistoric and historic sites in the CRE through tracking rates of erosion, visitor impacts, and other relevant variables. Determine the condition and integrity of TCPs in the CRE.

It is also directly responsive to the second highest priority CMIN for cultural resources:

> **CMIN 11.2.1.** Determine the condition of traditionally important resources and locations using tribal perspectives and values.

General Methods

Monitoring methods are being determined by each tribe in conjunction with completing their current (FY06 funded) contractual obligation with the Bureau of Reclamation.

Products/Reports

Before this project is initiated, a formal written report and oral presentation will be provided by each tribe to TWG in FY08 describing each tribe's proposed monitoring approach for FY08 and beyond.

An annual report documenting the assumptions, methods, annual outcome, and relationship of annual monitoring results to long-term status and trends of tribally valued resources, will be produced by each participating tribe at the conclusion of this study.

Budget (See Reclamation Budget for estimates)

CUL 11.R2.08: Implement Tribal Monitoring Projects	
	FY08

GCDAMP Goal 12: Maintain a high-quality monitoring, research, and adaptive management program

DASA 12.D1.08: Preparation for Monitoring Data Acquisition (remote sensing)

Start Date

October 2007

End Date

September 2008 (ongoing annually to support quadrennial, systemwide overflights)

Principal Investigator(s)

Glenn Bennett, Data Acquisition, Storage, and Analysis (DASA) Program Coordinator, GCMRC and Thomas Gushue, GIS Coordinator, GCMRC

Geographic Scope

Entire Colorado River ecosystem corridor from forebay of Glen Canyon Dam to upper Lake Mead

Project Goals/Tasks

Revision of current processing protocols, resolution comparison to determine applicable and efficient resolutions for area, volume, and classification techniques, FY09 mission planning and contract solicitation.

Need for Project

Although no remote sensing missions are currently planned until FY09, the DASA team within the GCMRC will annually task in preparation for the next scheduled canyonwide overflight.

A primary fiscal objective is to reserve sufficient funding to cover mission costs during implementation in 2009. Additionally, the data collection permit must be reviewed and updated through Grand Canyon National Park to reflect the types of remote sensing technologies that will be required to help fulfill the core monitoring and experimental research needs for all GCMRC programs. During FY08, mission planning and contract solicitation will begin for the next canyonwide data collection effort. Additionally, an evaluation of existing remotely sensed data previously collected by the GCMRC will be conducted to determine the appropriateness of different monitoring techniques and required data inputs to achieve desired accuracies for future core monitoring and research efforts in support of sediment storage, vegetation mapping, habitat classification and cultural site studies. This undertaking will involve an in-depth, simulation testing of data densities (resolutions) and editing requirements of inputs from a variety of sources including multi-band imagery, LiDAR, topographic data, hydrographic data and digital surface models. Two key aspects that this project will investigate are:

1. A revision of current processing protocols of these data sets that have previously resulted in a massive amount of manual editing before analysis,

2. An exploration of remotely sensed data at different resolutions (i.e., density of points) in comparison to final surfaces and classifications to determine the most applicable and efficient resolutions needed to achieve the necessary output with a minimum of error.

Particular attention will be given to data sets collected in conjunction with the 5-year research and development project (2001–6) for monitoring sand storage changes, however, additional canyonwide sand analysis will be conducted and statistical tabulations provided in support of resource monitoring for the cultural and biological programs. Included in this will be an extension of the 2002 sand/campsite analysis up through 2005 with particular emphasis given to effects of experimental flows on camping beaches.

In addition, image processing techniques will be explored in an effort to develop accurate ortho-rectification procedures of scanned analog overflight data sets and to achieve the best attainable classifications of resources along the Colorado River ecosystem (CRE). This will include the refinement of known or existing image processing techniques with the advent of more recent data sets and recent software developments to create automated procedures that allow for clear documentation of the analysis performed as well as establishing a platform for repeatable classification of riparian resources from similar data sets collected in the future.

Strategic Science Questions

The airborne data to be collected are multi-spectral orthorectified images of the CRE. Area and volumetric analysis of these data sets are used to identify and classify elements of interest. Comparison of data sets acquired over time allow for change detection as long as the data are continued to be collected. Airborne data is the basis for many of the science questions and research activities conducted in the Grand Canyon. Sandbar habitat change including vegetation encroachment, shoreline location and character at different flow regimes and the distance to cultural sites, backwater existence and changes, and maps used for positioning GCMRC monitoring areas are a few of the applications of airborne data. Some of the resource areas and science questions identified during the 2005 Knowledge Assessment and found within the GCMRC's Strategic Science and Monitoring and Research Plans (see Appendix A) that can be addressed with airborne image data include:

Other Strategic Science Questions

SSQ 4-1. Is there a "Flow-Only" operation (i.e. a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal time scales?

SSQ 5-1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and nearshore water temperatures throughout the CRE?

SSQ 1-7. Which tributary and mainstem habitats are most important to native fishes and how can these habitats best be made useable and maintained?

SSQ 2-1. Do dam controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?
SSQ 2-2. How do flows impact old high-water zone terraces in the CRE (where the majority of archaeological sites occur), and what kinds of important information about the historical ecology and human history of the CRE are being lost due to ongoing erosion of the Holocene sedimentary deposits?

SSQ 3-9. How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

Links/Relationships to Other Projects

Acquisition of systemwide, digital images in this project supports addressing numerous resource questions within other programs, such as abundance and systemwide distribution of both aquatic and terrestrial habitats related to fish, vegetation, as well as availability and status of campsites along the CRE. The digital products procured by the DASA directly support a varied array of projects within GCDAMP goals 1–11, such as detecting shoreline habitat and changes tied to dam operations and high-flow tests. Additionally, these data are used in terrestrial vegetation and sandbar mapping projects for determining surface texture and land cover classifications within designated study reaches, as well as canyonwide over subsequent years following the overflights (trend analysis).

Information Needs Addressed

Numerous GCDAMP goals and resource area programs that are concerned with remote sensing analysis are the chief beneficiaries.

IN 12.1. Develop information that can be used by the TWG, in collaboration with GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.

CMIN 4.1.6. Determine quantity and quality of spawning habitat for RBT in the Lees Ferry reach as measured at 5-year intervals.

CMIN 6.1.1. Determine and track the abundance, composition, distribution, and area of the marsh community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

CMIN 6.4.1. Determine and track composition, abundance, and distribution of the sand beach community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community.

CMIN 9.3.1. Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons.

RIN 6.1.1. How has the abundance, composition, distribution, and area of the marsh community changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of ROD operations (1996)?

RIN 8.6.1. How do ongoing inputs of coarse-sediment from tributaries influence storage of fine sediment within pools, runs and eddies throughout the CRE?

EIN 4.1.1. How does RBT abundance, proportional stock density, length at age, condition, spawning habitat, natural recruitment, whirling disease and other parasitic infections change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 6.1.1. How do marsh community abundance, composition, distribution, and area change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 6.4.1. How do the abundance, composition, and distribution of the sand beach community change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 9.3.1. How do the size, quality, and distribution of camping beaches change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

In total, approximately one-third of the GCDAMP information needs may be directly or indirectly addressed through analysis and use of the systemwide, digital imagery.

General Methods

Existing remote sensing data sets of different resolutions and point densities will be evaluated by DASA staff, on the basis of recommendations that were produced during the remote-sensing research and development initiative (2000–5), to determine if there are significant changes in volumetric calculations of surfaces and between various resource classifications will occur based on the density of values within the data.

Products/Reports

- A comprehensive data set will be made available that will allow analysis of existing and future remote sensing data will include surfaces at different resolutions by end of calendar year – December 31.

- A report comparing and assessing usefulness of these surfaces to the resolutions and accuracies needed for volumetric changes and sufficient resources classifications by end of calendar year – December 31.

- Also, GIS databases of elements of interest, location, and change between years of available remote sensing data can be developed and made available as well as a report documenting procedures used in the analysis and change witnessed during years in the study – see . DASA 12.D6.08: Integrated Analysis and Modeling—Mapping Shoreline Habitat Changes

Budget

DASA 12.D1.08	
Preparation for Monitoring Data Acquisition (Remote Sensing; FY08–Ongoing)	
	Fiscal Year 2008
	-
	-
	-
	-
	-
	-

DASA 12.D2.08: Grand Canyon Integrated Oracle Database Management System

Start Date

October 2007

End Date

September 2008, and ongoing annually

Principal Investigator(s)

Glenn Bennett, Data Acquisition, Storage, and Analysis (DASA) Program Coordinator, GCMRC and Paul Alley, Database Administrator, GCMRC

Geographic Scope

The entire GCMRC study area, from the forebay of Lake Powell to upper Lake Mead

Project Goals/Tasks

The goal of the database management system at GCMRC is to provide an organized, secure and readily available electronic repository for all scientific data collected in the ongoing research and monitoring activities of the center. The Relational Database Management System (RDBMS) also serves as the electronic storage foundation of the Center's GIS, providing the repository for all aerial photography, survey control and geographic layers. The program is therefore a vital component of the decision support process and for the adaptive management of the Glen Canyon Dam (GCD). In support of these goals, the following are tasks will be completed during FY08:

- Electronically archive all incoming data sets in their original form
- Error check and import newly collected data sets to the centralized RDBMS
- Administer database, including backup, recovery, and security
- Continue to consolidate and import legacy data to the system
- Continue to support data acquisition, import and analyses by disciplines such as fish and water sampling in the Colorado River, and survey control
- Extend database structure to incorporate newly acquired data sets, such as aquatic food base and daily down stream water quality
- Develop routines to automate the process of error checking and importing data sets
- Extend Web application architecture to distribute newly collected data sets
- Provide data analysis support for scientific monitoring and research analyses

Need for Project

This project establishes the electronic repository and tools necessary to analyze and interpret scientific data collected by the center, thereby providing a fundamental support service to GCMRC scientific investigations and decision support processes.

Strategic Science Questions

This project provides the foundation for all projects concerned with scientific data analysis.

Links/Relationships to Other Projects

Most programs generate data sets that will be archived, served and analyzed using DASA database services. The best example of the power and utility of the Oracle database is its ability to handle terabytes of data generated of multiple years, such as those data that are associated with systemwide, airborne, digital imagery.

Information Needs Addressed

Provides access for analysis for all GCMRC data sets.

> **IN 12.1.** Develop information that can be used by the TWG, in collaboration with GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.
>
> **RIN 12.3.1.** As necessary, investigate the most effective methods to integrate and synthesize resource data.
>
> **RIN 12.5.4.** What is the most effective way to distribute information to our stakeholders and the public in a secure and accessible fashion?

General Methods

Working with data stewards from each scientific program at GCMRC, the integrated database design will be extended in modular fashion to accommodate both newly collected data, such as with aquatic food base monitoring, and legacy data that have yet to be imported into the Relational Database Management System. This process involves extensive review of existing data sets as well as current data collection protocols, and the information needs of each discipline. As these information needs are fully understood by programming staff, applications will be written that enable users to extract related data sets from the RDBMS and perform appropriate analyses. Generally these applications are written with a Web interface, as this technology provides the greatest flexibility and availability.

Products/Reports

- Fine grained sediment transport module and Web application (3rd quarter FY08)
- Aquatic food base module and Internet/Intranet application (4th quarter FY08)
- Downstream water quality and temperature Web application (4th quarter FY08)

If above products completed ahead of schedule, the following products will be produced as time permits:

- Terrestrial biology database module and Web application
- Kanab ambersnail database module
- Survey control point module and Web application
- Stanton repeat photography Web application
- Extended database design document to include new data sets
- Metadata Web application

Budget

DASA 12.D2.08	
Grand Canyon Integrated Oracle Database Management System (FY08–Ongoing)	
	Fiscal Year 2008

DASA 12.D3.08: Library Operations

Start Date

October 2007

End Date

September 2008, ongoing annually

Principal Investigator(s)

Glenn Bennett, Data Acquisition, Storage, and Analysis (DASA) Program Coordinator, GCMRC and Stephanie Mietz-Wyse, Technology Information Specialist, GCMRC

Geographic Scope

Entire GCMRC study area—forebay of Glen Canyon Dam (GCD) and upper Lake Mead

Project Goals/Tasks

Library operations facilitate monitoring and research by providing a centralized repository for hard copy information such as books, reports, maps, photography, and videos.

Need for Project

The GCMRC library acts as the physical repository for reports and data generated by GCMRC scientists as well as materials related to the Colorado River, Grand Canyon and Adaptive Management.

Strategic Science Questions

This project provides a research resource to aid in answering science questions.

General Methods

The library catalogs all new materials that come from staff scientists, contractors, and cooperators as well items related to Grand Canyon, the Colorado River, and Adaptive Management. Library staff provides support to cooperators, contractors, and staff scientists by researching and obtaining current and legacy articles and reports related to science projects.

Library operations facilitate monitoring and research by providing a centralized repository for hard copy information such as books, reports, maps, photography, and videos.

Links/Relationships to Other Projects

This project supports all other projects.

Information Needs Addressed

The library provides access to current and historical scientific findings of the GCDAMP.

> **RIN 12.5.4.** What is the most effective way to distribute information to our stakeholders and the public in a secure and accessible fashion?

Products/Reports

- Online library catalog which provides access to more than 8,000 publications continually updated
- Catalog records of all materials – continually updated
- Monthly update of new reports received in the library
- Assistance to cooperators, stakeholders, media contacts, and the public by providing access to reports, aerial photos, maps, slides, and photos in hardcopy and digital form
- Research in locating contemporary and legacy materials
- A research facility for researchers, GMCRC employees, cooperators, and the public

Budget

DASA 12.D3.08	
Library Operations (FY07–Ongoing)	
	Fiscal Year 2008

DASA 12.D4.08: Legacy Analog Data Conversion (Analog to Digital – Reports and Imagery)

Start Date

October 2007

End Date

September 2008, and ongoing through 2012

Principal Investigator(s)

Glenn Bennett, Data Acquisition, Storage, and Analysis (DASA) Program Coordinator, GCMRC; Stephanie Wyse-Mietz, Technology Information Specialist, GCMRC; and Esther Quinn, Computer Assistant, GCMRC

Geographic Scope

Entire GCMRC study area—forebay of Glen Canyon Dam (GCD) and upper Lake Mead

Project Goals/Tasks

The library has undertaken a project to convert all materials in the library to digital format and make them accessible and searchable on the GCMRC Web site. Having materials available through the Web site will allow multiple users to access data concurrently from remote locations as well as protect unique items from damage or loss. Overflight imagery digitally available for spatial analysis will extend the historical spatial record allowing change detection throughout the Colorado River ecosystem.

Need for Project

The conversion project will allow for greater access to and protection of legacy and current materials.

Strategic Science Questions

This project provides a research resource for answering spatially defined science questions and extending the period of record of digitally available overflight imagery.

Links/Relationships to Other Projects

This project supports projects concerned with spatial change over time.

Information Needs Addressed

This project supports projects concerned with spatial change over time.

IN 12.1. Develop information that can be used by the TWG, in collaboration with GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.

CMIN 6.1.1. Determine and track the abundance, composition, distribution, and area of the marsh community as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community

RIN 6.1.1. How have the abundance, composition, distribution, and area of the marsh community changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?

RIN 6.4.1. How have the abundance, composition, and distribution of the sand beach community changed since dam closure (1963), high flows (1984), interim flows (1991), and the implementation of Record of Decision operations (1996)?

EIN 6.1.1. How do marsh community abundance, composition, distribution, and area change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

General Methods

The scanning conversion project involves:

1. Scanning and converting paper reports into digital pdf files, making the documents searchable by using Optical Character Recognition (OCR) software, and then posting the files in the library database on the GCMRC Web site.

2. Scanning all analog aerial film and photos using the Vexcel Ultrascan 5000. Digital results can then be used for 2D and 3D change detection.

3. Digitizing Flight line maps to provide a searchable mechanism to locate individual scanned aerial photos.

4. Converting VHS tapes to DVDs

5. Scanning all legacy slides to create digital images using the Nikon SuperCoolScan scanner

Products/Reports

Access to 17,652 aerial photographs, 9,000 digital aerial images, 8,000 hardcopy reports, 8,000 photos and slides, and 700 videos in broadcast and VHS format. In addition, once the library scanning project is complete, this information will be available in digital format from the library via digital media such as DVD and online via the World Wide Web.

As these conversion products are produced, they are cataloged and made available: see DASA 12.D3.08: Library Operations.

Budget

DASA 12.D4.08	
Legacy Analog Data Conversion (Analog to Digital - Reports & Imagery; FY08–FY11)	
	Fiscal Year 2008

DASA 12.D5.08: GIS General Support for Integrated Analyses and Projects, GIS Lead

Start Date

October 2007

End Date

September 2008, ongoing annually

Principal Investigator(s)

Glenn Bennett, Data Acquisition, Storage, and Analysis (DASA) Program Coordinator, GCMRC and Thomas Gushue, GIS Coordinator, GCMRC

Geographic Scope

Entire Colorado River ecosystem corridor between Glen Canyon Dam and Lake Mead, and the greater Colorado River Basin

Project Goals/Tasks

Specialized maps, advanced spatial analysis, and intuitive data retrieval

Need for Project

The traditional role of the GIS program is inherently service-oriented, providing spatial database development, programming and analysis support to the science programs and their cooperators on both a planned and an as-needed basis. To continue functioning in this capacity it is imperative to factor in designated blocks of time to maintain and in some cases improve the level of GIS support. GIS general support benefits core monitoring, experimental programs, and research and development projects alike in the form of GIS and Remote Sensing software installation, maintenance and support, creation and maintenance of spatial databases used by science projects, and the development of mapping and analysis tools for use by GCMRC staff and cooperators across all resource programs. There is also a need for a higher level of support for more specific GIS application development and analysis of available spatial data. This higher level of support is often achieved through automation of data processing and manipulation procedures to standardize and streamline repetitive tasks as well as provide a basis for standard operating procedures.

Strategic Science Questions

The spatial aspects of Grand Canyon investigations are addressed in this project.

Links/Relationships to Other Projects

Most GCMRC projects have a spatial component tied to the data being collected in support of the science questions developed for each project. The GIS provides a stable platform upon which all data collected along the CRE are catalogued within a consistent spatial reference system. At the most basic level, this allows for the overlaying and querying of data sets collected from any and all projects within GCMRC.

Information Needs Addressed

Classification, inventory, and change detection of geomorphic, biological, and cultural areas and volumes.

> **IN 12.1.** Develop information that can be used by the TWG, in collaboration with GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.
>
> **RIN 12.3.1.** As necessary, investigate the most effective methods to integrate and synthesize resource data.
>
> **RIN 12.5.4.** What is the most effective way to distribute information to our stakeholders and the public in a secure and accessible fashion?

General Methods

The collection of spatial data is achieved through a variety of methods that include, but are not limited to, remote sensing data collection missions, traditional survey and GPS operations, field mapping using hardcopy map or pen tablet computers, on-screen digitizing using previously collecting remote sensing data as source information, and through other standard data entry methods. Spatial data are generally stored in one of the standard ESRI file types (shape file, coverage, geodatabase) as well as in ASCII format. Methods used for spatial data processing and analysis will vary depending on the questions that need to be answered.

Products/Reports

Throughout the year production of products derived from GIS support include maps for publications, generation and printing of maps and graphics for posters, creation of improved base maps for Lake Powell and Grand Canyon, instructional sessions for staff, cooperators and contractors on GIS layer development, integration and analysis, and advanced spatial analysis for monitoring projects.

Budget

DASA 12.D5.08	
GIS Support for Integrated Analyses and Projects, GIS Lead (FY07–Ongoing)	
	Fiscal Year 2008

DASA 12.D6.08: Integrated Analysis and Modeling—Mapping Shoreline Habitat Changes

Start Date

October 2007

End Date

September 2008, and ongoing through FY11

Principal Investigator(s)

Glenn Bennett, Data Acquisition, Storage, and Analysis (DASA) Program Coordinator, GCMRC; Thomas Gushue, GIS Coordinator, GCMRC; Stephanie Wyse-Mietz, Technology Information Specialist, GCMRC; Timothy Andrews, Geographic Information Systems Engineer, Utah State University; and Michael Breedlove, Ph.D., Geographer, Utah State University

Geographic Scope

Entire Colorado River ecosystem corridor between forebay of Glen Canyon Dam (GCD) and upper Lake Mead

Project Goals/Tasks

Shoreline habitat classification and change detection of shoreline habitat for the following years: 2002, 2004, and 2005.

Task 1: Review, refine and implement edits to Surficial Geomorphic Classes. .

Task 2: Development a draft coverage of vegetated and non-vegetated GIS layers for both 2002 and 2005.

Task 3: Define methods for backwater delineation and on-screen digitizing of backwater polygons. Spatial data set inventory of backwaters for 2002 and 2005 imagery data sets.

Task 4: Change detection, statistical analysis, and tabulations

Need for Project

A wealth of remote sensing data have been collected over the past few years in support of various core monitoring and experimental programs within GCMRC. However, the full value of these data have yet to be realized due to a lack of time between consecutive data collection missions to process these data into more usable information. Currently, a need exists to utilize these data to study the shoreline environment along the CRE downstream of GCD. A baseline data set of shoreline habitat currently exists as a linear classification of six habitat types at 8,000 cfs for the year 2000. Three other remote sensing data sets exist for the years of 2002, 2004, and 2005 which will be used to extend the time series of the shoreline habitat for a 5-year period. Additionally, a

need exists to expand this classification into higher stages (above 8,000 cfs up to at least 45,000 cfs) in an effort to better correlate shoreline habitat with fish data and recreation habitat data also collected by GCMRC and its cooperators. The original classification scheme for the shoreline will be extended to include backwater habitats, providing an update to the existing USU backwater data set up to the year 2005 (Goeking and others, 2005). In addition to the classification effort, an automated suite of methods could be developed to facilitate shoreline change detection across a range of stages.

Strategic Science Questions

SSQ 3-9. How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

SSQ 1-4. Is there a "Flow-Only" (non-sediment augmentation) operation that will restore and maintain sandbar habitats over decadal time scales?

SSQ 4-2. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs (displacement and possibly mortality of young humpback chub) associated with high flows?

Other science questions:

- What is the rate of change in eddy storage (erosion) during time intervals between BHBFs?
- What are the most appropriate methods for detecting change in shoreline habitat along the entire CRE given the available data sets collected using different technologies (scanned-analog vs. digital), different platforms (Leica ADS-40/ISTAR vs. DMC/3001, Inc.), and different image resolutions (30cm vs. 22cm vs. 18cm)? What is the most appropriate scale/minimum mapping unit to map the shoreline habitat for all years in order to support related science questions?
- What level of change can be detected in shoreline habitat using remotely sensed data collected in the past 5 years? What changes have occurred to the shoreline habitat across the CRE in the past 5 years?
- Where have the most significant changes taken place in shoreline habitat along the CRE in the past 5 years, and within which shoreline habitat classes are the most noticeable changes? How does the shoreline habitat relate to backwater environments/habitats? What have been the changes in backwater abundance/size/shape over the past 5 years?
- As historical analog over flights become available in digital format, can the timeline be extended back to previous years?

A time-series comparison of shoreline characteristics may prove quite useful for the following AMWG priorities:

Which tributary and main stem habitats are most important to native fishes and how can these habitats best be made useable and maintained?

A time series comparison of backwater change in size and existence/non-existence of habitats may answer questions of species abundance due to changing availability of usable habitat. Other changes in shoreline characteristics may provide insight on non-backwater habitats utilized in different lifecycle stages.

Links/Relationships to Other Projects

A number of projects in the past few years have used the shoreline habitat data developed from the March 2000 imagery data set. Shoreline habitat type has been used in conjunction with native and nonnative downstream fish sampling in the mainstem of the Colorado River, and it has also been used as a guide to delineate sampling sites of 'Redds' in Glen and Marble Canyons. Similarly, this data is currently being incorporated into the new aquatic food base initiative at GCMRC. This layer has also been applied to studies of the terrestrial environment including the vegetation mapping project and initial campsite monitoring efforts conducted over the past 2 years. It is expected that new, more recent classifications will be used in similar fashion for future analysis.

Information Needs Addressed

IN 12.1. Develop information that can be used by the TWG, in collaboration with GCMRC, to establish current and target levels for all resources within the GCDAMP as called for in the GCDAMP strategic plan.

CMIN 4.1.6. Determine quantity and quality of spawning habitat for RBT in the Lees Ferry reach as measured at 5-year intervals.

CMIN 8.2.1. Track, as appropriate, the biennial sandbar area, volume and grain-size changes outside of eddies between 5,000 and 25,000 cfs stage, by reach?

CMIN 8.4.1. Track, as appropriate, the annual sandbar area, volume and grain-size changes within eddies between 5,000 and 25,000 cfs stage, by reach?

CMIN 8.5.1. Track, as appropriate, the biennial sandbar area, volume and grain-size changes above 25,000 cfs stage, by reach?

CMIN 9.3.1. Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons.

RIN 6.1.1. How has the abundance, composition, distribution, and area of the marsh community changed since dam closure (1963), high flows (1984), interim flows (1991) and the implementation of Record of Decision operations (1996)?

EIN 6.1.1. How do marsh community abundance, composition, distribution, and area change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 6.4.1. How does the abundance, composition, and distribution of the sand beach community change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 9.3.1. How do the size, quality, and distribution of camping beaches change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Products/Reports

Spatial databases, spatial analysis results, and associated metadata.

1. Surface texture classifications for entire river corridor (Glen Canyon Dam to Lake Mead) for years 2002, 2004, and 2005. This will include spatial data sets representing Coarseness (Rough vs. Smooth) including Sand / No Sand data. (By end of calendar year – December 31)

2. First level Normalized Difference Vegetation Index (NDVI) for entire river corridor for 2002 and 2005 imagery data sets using the NIR and Red bands of the remote sensing imagery. Resultant GIS layers will show generalized vegetated vs. non-vegetated areas canyon-wide for both data sets. (By end of calendar year – December 31)

3. Surficial Geomorphic classifications (Cliff, Talus, Debris Fan, and Cobble Bar) for entire river corridor as based on existing classification scheme (March 2000 shoreline). Resultant GIS polygons will represent these broad geomorphic classes. (By end of calendar year – December 31)

4. Update and extend USU backwater time series through year 2005. GIS polygon layer will show inventory for interpretable backwater areas from 2002, 2004 and 2005 imagery data sets. (By end of calendar year – December 31)

5. Final composite shoreline classification scheme and computer programs for generating surface texture and surficial geomorphic classifications and shoreline habitat attributes. Methodology and procedures will be documented for further application with future remote sensing data collections. (By end of calendar year – December 31)

6 Nearshore habitat classifications and statistical summaries for selected canyon-wide flow regimes (By end of calendar year – December 31)

7. Recommendations for future updates, enhancements. (By end of calendar year – December 31)

Budget

DASA 12.D6.08	
Integrated Analysis and Modeling - Mapping Shoreline Habitat Changes (FY08)	
	Fiscal Year 2008

Logistics, Support, and Control

SUP 12.S1.08: Logistics Base Costs

Start Date

Ongoing

End Date

Ongoing

Principal Investigator(s)

Carol Fritzinger, Logistics and Survey Program Manager, GCMRC

Geographic Scope

Entire Colorado River ecosystem corridor between Glen Canyon Dam and Lake Mead, and the greater Colorado River Basin

Project Goals/Tasks

Provide logistical support for GCMRC projects

Need for Project

The GCMRC will provide complete logistical support for 25 t o 40 research, monitoring, and administrative river trips through the Grand Canyon annually. These trips range in length from 7 to 21 days and from 4 to 36 people in size. Trips will be comprised of a variety of motor and oar powered boats operated by contracted boat operators. Projects operating in the Glen Canyon reach of the Colorado River (Glen Canyon Dam to Lees Ferry) will be supported by a variety of motor powered boats operated by GCMRC researchers and contracted boat operators. Additionally, research activities on the Little Colorado River and at other locations outside of the Grand Canyon National Park boundaries are supported by helicopter services contracted with the Bureau of Reclamation. Ground-based support for other research activities outside of the river corridor are also coordinated with the use of GCMRC leased vehicles.

Strategic Science Questions

N/A

Links/Relationships to Other Projects

All GCMRC projects which have field data collection components are supported by the GCMRC logistics program.

Information Needs Addressed

N/A

General Methods

The GCMRC will use government owned boats and river logistical equipment in conjunction with a contracted vendor who supplies technical and logistical boat operators. Put-in and take-out transportation is provided with the use of General Service Administration (GSA) leased vehicles and contracted shuttle drivers.

Effective communication with principal investigators and sensitivity to and awareness of the challenges they face in implementing their studies enable the GCMRC to offer more customized (and therefore more cost-effective and productive) logistical support than other support strategies utilized previously. Retaining control over the process of supporting trips also facilitates compliance with National Park Service (NPS) regulations and allows greater control over issues sensitive to the general public and the "recreational river community."

Products/Reports

Research projects supported by the GCMRC must obtain required permits in compliance with Federal, State, Tribal, and local agencies in which project activities are conducted. Research activities conducted within Grand Canyon National Park and Glen Canyon National Recreation Area require NPS Research and Collecting Permits and Access Permits for all river launches, back country use, over flights, and media (filming) production. All NPS permits acquired for GCMRC supported projects are processed and submitted by the GCMRC Logistics Coordinator to the NPS Science Center Research Permitting Coordinator.

Budget

SUP 12.S1.08	
Logistics Base Costs (Other costs dispersed throughout projects; Ongoing)	
	Fiscal Year 2008

SUP 12.S2.08: Survey Operations

Start Date

Ongoing

End Date

Ongoing

Principal Investigator(s)

K. Brown, U.S. Geological Survey, Grand Canyon Monitoring and Research Center

Project Goals/Tasks

1. Supply GCMRC principal investigators with the necessary equipment, supplies, and survey knowledge to perform the spatial data collection required by their research.
2. Provide updated control point coordinates and associated errors to researchers as well as any associated processed survey data required by researchers to complete analysis.
3. Collect control point descriptions to publish and populate in the Control Point Database.
4. Publish control point atlas and make them available for all CRE field survey activities
5. Translate and rotate historical survey data sets to updated network control coordinates
6. Integrate the prioritized historical survey datasets into the CRE database
7. Educate principal investigators and researchers regarding the limits of various mapping techniques.
8. Evaluate innovative mapping techniques supporting research goals.
9. Publish reports 1) evaluating ground-base LiDAR techniques for monitoring cultural sites, and 2) ground-based LiDAR, oblique photogrammetry, to survey techniques as alternative methods for collecting topographic data.

Need for Project

Grand Canyon Monitoring and Research Center (GCMRC) is charged with providing credible, objective scientific information to the Glen Canyon Dam Adaptive Management Group on the downstream resources of the Colorado River using an ecosystem wide approach. This approach requires that physical, biological and cultural spatial data be integrated into a regional Geographic Information System (GIS) database to allow for accurate, long-term change detection analysis of CRE resources and for interrelationship analysis between CRE resources. All spatial data collected under the direction of the GCMRC requires referencing to the geodetic control network established by the National Geodetic Survey and the GCMRC which allows for accurate change detection computations including volumetric and surface area computations. Survey operations support research and monitoring activities by collecting survey data following survey protocols, and by delivering the data in formats consistent with the established data standards. Survey operations maintain survey equipment for field use including conventional total station equipment, static, kinematics and Real Time Kinematics (RTK) GPS equipment, digital cameras, hand-held communication devices (radios), echo sounders, acoustic Doppler and bathymetry systems, and field control point atlas.

GCMRC's survey department supports the research needs of the scientists and includes acquiring topographic data, positioning remotely sensed data, evaluating innovative mapping techniques that support research goals, validating accuracy of topographic and spatial data, and compiling and updating historical data. The survey support offered by GCMRC allows consistent data collection methods by technically trained personnel familiar with the surveying equipment and the logistical constraints of Grand Canyon fieldwork. Collection of topographic and spatial data enables comparison and analysis in the GIS database to monitor change. Data storage and database protocols for all survey data are developed maintained by the survey department to ensure consistency and permit straightforward integration into the GIS database. The GIS database is referenced to the geodetic control network of highly accurate real-world coordinate values for control points from which measurements computing change are calculated. Historical, current and future data are referenced to the control network ensuring a common reference system between data sets collected for ecosystem monitoring studies, research and analysis.

General Methods

Survey operations is primarily responsible for assisting researchers collect and use field measurements for scientific investigations to achieve accurate spatial data with realistic error assessments for reliable data analysis and database integration. This responsibility is either comprised of collecting field data whereby the survey operations obtains, maintains and upgrades all survey equipment required to fulfill project needs, or is comprised of updating historical legacy data for analysis inclusion into the GIS database. Associated with updating legacy data, survey operations is currently collecting control point information to populate a control point database which concurrently verifies existence and condition of control points along the CRE, and include historical control points. Furthermore, the survey department advises researchers on the appropriate methods of collecting topographic or spatial data to meet the requirements of a scientific study as well as evaluates new technology and its applicability to research and monitoring projects.

Survey operations in support of programs within GCMRC are summarized in the following list:

1. Positioning of historically and newly collected spatial data.
2. Reference historical spatial data to modern control network.
3. Populate the Control Point Database.
4. Quality Assurance/ Quality Control of spatial data.
5. Evaluate innovative mapping techniques
6. Maintain and upgrade equipment

Control points are established and spatial data is collected using both GPS and conventional survey methods. Surveys follow protocols developed by GCMRC with technical support from the National Geodetic Survey, Army Corps of Engineers, and the Federal Geodetic Data Committee.

Integration: All programs within the GCMRC require spatial data measurements. Integration with each program's requirements and the GIS database is imperative to the process of survey data collection, post-processing, storage, and evaluation. The survey department is available to all GCMRC principal investigators and can often collect data for multiple projects during the same mission.

Consequences of FY08 Funding Recommendations: Funding will allow for more historical datasets to be integrated into the GIS database for accurate change detection. Additional funds will be preserved by attaining accurate positions and elevations of spatial data before integration into GIS database. The all survey equipment will be maintained and/or upgraded.

Implications of Experimental vs. Non-Experimental Scenarios: Under the "With Experiment" scenario, the funding available to support survey activities is reduced and this reduction will delay progress to some degree on the development of the Control Point Database, and updating of legacy data. Under the "Non-Experimental" scenario, funds for this area of the program are the same as originally proposed in the February 2007 version of the work plan.

Budget

SUP 12.S2.08	
Survey Operations	
	Fiscal Year 2008

SUP 12.S3.08: Control Network (Ongoing)

Start Date

Ongoing

End Date

Ongoing

Principal Investigator

Keith Kohl, Grand Canyon Monitoring and Research Center

Geographic Scope

Geodetic control now encompasses the entire CRE corridor between Glen Canyon Dam and Lake Mead, and the greater Colorado River Basin

Project Goals/Tasks

The objective of this project is to develop a high-precision control network throughout the CRE. Control monuments will be established at consistent intervals throughout the CRE and at locations required for accurate positions and elevations of past, current, and future data sets. The goal of this project is the expansion of the control network into the necessary areas before spatial data collection required by GCMRC research and core monitoring activities. Having stable control monuments and accurate coordinates completed before spatial data acquisition begins allows for reduction in the effort required in post-processing methods, and conservation of both human and funding resources. Historical data sets are accurately rectified for integration into the data base.

Need for Project

The geodetic control network serves as the foundation for all spatial measurements necessary for long term monitoring. This control network also serves as the spatial framework for the GIS. The referencing of spatial data must be consistent in order to perform accurate change detection. All spatial data collected within the CRE requires geo-referencing to the primary geodetic control network established by the National Spatial Reference System, GCMRC, and the National Geodetic Survey (NGS). While current remote sensing and long-term monitoring sites have been referenced to this network, additional GCMRC monitoring activities require expanded network control efforts.

It has been shown that horizontal positions can be efficiently attained with the use of GPS techniques. While the vertical component is more problematic, heights referencing the ellipsoid can be effectively calculated throughout much of the CRE. These horizontal and vertical coordinates are required for previously collected data sets before inclusion in the CRE Oracle database. Spatial reference is also required in areas of future data collection to eliminate the need to translate and rotate surveys collected in local or superseded coordinate systems. Substantial

project cost savings are achieved when the geodetic control is established within study areas before field data collection in support of monitoring and research projects.

Quality Assurance/Quality Control (QA/QC) is required for all remotely sensed spatial data sets. The Colorado River ecosystem Elevation Database is designed to give positions and elevations at visible “hard points” along the river corridor. This dataset can be used to check accuracy of LiDAR (Horizons, John Chance) and digital aerial photography (ISTAR, 3001 Inc.) remote sensing techniques, both on a canyon-wide basis and for a local assessment of position and height accuracies of each day’s flight. With the high cost of remote sensing data collection, QA/QC is critical to analyzing the usefulness of each data subset. Additionally, this elevation database can also be used to geo-reference scanned photos from previous missions to study change detection.

Strategic Science Questions

All spatial data aspects of Grand Canyon investigations are addressed in this project.

Links/Relationships to Other Projects

Accurate spatial positioning of scientific data from the cultural, biological, and physical programs is necessary for facilitating change detection methods. Historical data must be adjusted to reliable coordinates before integration into the database and before resource assessments can be made. Often, past surveys that relate to current monitoring efforts have been referenced to local datums. These sites also require accurate positional and height data before the data can be entered into the GIS database for examination and change detection.

Information Needs Addressed

Accurate spatial positioning of scientific data collected within the cultural, biological, and physical programs are necessary for facilitating change detection methods.

General Methods

Control points are established using both GPS and conventional survey methods. GPS techniques utilize relative positioning where antennas and receivers are placed at both known and unknown network positions. Distances are measured between the known and unknown points by time dependant calculations from GPS satellite data. Conventional survey techniques involve the use of a total station (a survey instrument which combines the horizontal and vertical angle measurement abilities of a transit with electronic distance measurements). Conventional traverse surveys begin at a known reference point, measure through a series of line-of-sight stations, and close at either the point of beginning or another known reference point. Both conventional and GPS measurements will be required for 1) coordinate determinations of positions and elevations throughout the CRE, and 2) realistic error estimates for each network control station.

Products/Reports

The products of the CRE control network project will be:

A network of survey control points established in specific research areas and throughout the CRE, referenced to the NSRS2007 established by the Grand Canyon Monitoring and Research Center and the National Geodetic Survey.

A published paper on the geodetic control network and efforts can be expected in FY08. The paper will include methods, results, coordinates and realistic positional and height accuracy estimates for all network control stations and photo-identifiable fixed points. The paper will also evaluate the ability of Geoid 2003 to model NAVD88 orthometric heights from GPS derived ellipsoidal heights.

A separate paper will be written offering standards for all spatial data collection within the Adaptive Management program. This paper will be presented to the Spatial Positioning Protocol Evaluation Program (PEP) targeted for autumn 2008. The panel will review the document and provide further recommendations for center-wide use and acceptance. This document will provide standards and specifications for both in-house and contractual spatial data collection requirements for all collection including the 2009 remote sensing mission.

Coordinate results and index maps showing the locations of the network control stations, as well as QA/QC photo-identifiable fixed points which will be used to geo-reference past datasets and evaluate horizontal and vertical accuracies of current remotely sensed data.

GIS layers with control station information.

Budget

SUP 12.S3.08	
Control Network (On-going)	
	Fiscal Year 2008

PLAN 12.P1.08: Enhancing the Conceptual Ecosystem Model to Identify Critical Ecosystem Interactions and Data Gap (First priority to be funded with any additional FY08 funds that become available)

Start Date

October 2007

End Date

September 2008

Geographic Scope

The entire GCMRC study area, from fore bay of Lake Powell to upper Lake Mead

Principal Investigator(s)

John Hamill, Chief, GCMRC

Project Goals/Tasks

In FY07–FY08, GCMRC will work with the Science Advisors (SA) to identify and incorporate more robust integrated ecosystem science approaches into its overall program effort. The first step will be to evaluate redesign and expansion of the Colorado River ecosystem (CRE) conceptual ecosystem model (CEM). A preliminary list of priority expansions of the CRE model include:

- Expanding the fishery elements to address coldwater and warmwater fish predation on humpback chub (HBC), young-of-year (YoY) HBC habitat use, etc.
- Modeling outcomes of non-flow management activities (i.e., operation of a temperature control device, mechanical removal of nonnatives, translocation efforts for HBC, tributary triggers for beach/habitat-building flow (BHBFs))
- Linking Lake Powell and downstream temperature simulations to fine-sediment, food web, and fisheries sub-models
- Expanding the model to provide a broader landscape perspective by incorporating Lake Powell, the Lower Colorado River, and Paria River and addresses relationships to terrestrial habitats in the CRE
- Enhancing the use of climatic input data and simulations
- Recreational use and campsite size/abundance/distribution
- Cultural site change and protection strategies (archaeological sites, traditional cultural properties).
- Financial impact simulations coupled to the flow/dam operations sub-models.

GCMRC proposes to recruit a part-time/visiting ecosystem scientist/ ecologist to work with GCMRC staff and cooperators to develop and implement an integrated, interdisciplinary ecosystem science program. The primary focus of the visiting scientists will be to integrate SA recommendations and results of the CEM exercise into the GCMRC science program. The efficacy of this action will be reviewed based on the SA's above proposed evaluation/recommendations related to opportunities for incorporating an ecosystem science approach into the current science program.

Need for Project

Conceptual models summarize our current understanding of ecosystem or community function, or species life history, clarify likely responses to management actions and pressures (i.e., stressors, causes of change) (Atkinson and others, 2004). Figure 1 illustrates the role of conceptual model in the GCDAMP adaptive management process. In 1998, Walters and others (2000) conducted an Adaptive Environmental Assessment and Management Workshop to assist Grand Canyon scientists and managers in development of a conceptual model of the CRE affected by GCD operations. The model proved to be useful at helping to understand the relationship among various ecosystem components and identify knowledge gaps and predict the response of some ecosystem components to policy change. However, it was lacking in its ability to predict the effects of policy decisions on several key areas such as long-term sediment storage, fisheries response to habitat restoration, and socio-economic effects. Expanded design, development, and use of the conceptual ecosystem model is needed to increase its utility in ecosystem science planning and management processes, to make it more user friendly to scientists and managers, and to provide information that is relevant to each high priority GCDAMP goal/question.

Strategic Science Questions

The model will be directed at addressing priority AMWG questions and information needs and related strategic science questions in an integrated modeling effort.

Link/Relationship to Other Projects

One of the primary purposes of the CEM is to identify the linkages and relationships between various ecosystem components. Information derived from the model will assist in identifying data gaps and critical dependencies between/among science projects and allow for the effective design of an integrated, interdisciplinary science program.

Information Needs Addressed

N/A

General Methods

1. GCMRC will work with the SA and TWG to review the current CEM and identify needed updates and revision (FY08).

2. A RFP will be developed/issued to update the CEM in accordance with the findings and recommendations of the SA (FY08).

3. Two conceptual modeling workshops will be held to revised/updated model to address GCDAMP information needs and to identify data gaps and experiments or R&D project to fill critical data gaps (FY08). The workshops will be planned and conducted by the contractor.

4. Recruit a part-time/visiting ecosystem scientist/ ecologist to work with GCMRC staff and cooperators to develop and implement an integrated, interdisciplinary ecosystem science program (FY08–FY09).

Products/Reports

- SA recommendations for enhancing the CEM and improving integrated ecosystem science in the GCDAMP
- A revised and fully documented CEM (with metadata)
- Report of workshop activities, results and recommendations

Budget

Plan 12.P1.08	
Enhancing the Conceptual Ecosystem Model to Identify Critical Ecosystem Interactions and Data Gap	
	Fiscal Year 2008

1. $75,000 for visiting scientist
2. $125,000 for CEM revisions, workshops, and reports
3. GMMRC costs covered under Program Management and DASA support
4. SA costs covered under SA budget

PLAN12.P2.08: GCDAMP Effectiveness Workshop Follow-up

Start Date

November 2007

End Date

October 2008

Principal Investigator(s)

GCMRC will administer the project for the AMP. An AMP Project Advisory Group will help design and oversee the workshop follow-up activities.

Geographic Scope

Glen Canyon Dam Adaptive Management Program

Need for Project

In FY08, an AMP Effectiveness Workshop will be conducted that focuses on the following recommendations from the Roles Ad Hoc Group Report (2007).

- Establish a common mission/goal for the AMP
- Create incentives for participants to work collaboratively to achieve common goals and desired future resources conditions
- Define desired future resources conditions
- Update or develop a charter and operating procedures for all the elements of the AMP (AMWG, TWG, GCMRC, and Secretary's Designee) to reflect a more collaborative approach. All parties need to clearly understand the mission and responsibilities of the group they serve on and the protocols or processes for how business will be conducted
- Utilize facilitation and mediation expertise more broadly throughout the AMP
- Establish a full-time executive coordinator/manager for the program
- Determine is there is adequate time for collaboration to be successful
- Determine if a balanced range of interests are willing to participate

A goal of the FY08 AMP Effectiveness workshop is to develop and complete an action plan to address the above issues and recommendations over the next 5 years. In addition the roles report includes a variety of

There is a need to provide funding to support continued facilitated discussion related to these topics and the other recommendations included in the Roles Report for improving the effectiveness of the AMP. Issues that may be examined in follow-up workshops may include:

1. What strategies/approaches are most suitable for more effectively (a) addressing the value based conflicts reflected by the diverse interests in the GCDAMP and (b) integrating the use of scientific information into the GCDAMP process?

2. What improvements could be made in GCDAMP structure, procedures, and operations (looking individually at AMWG, TWG, GCMRC, and SAB) to improve efficiency and effectiveness of the overall program?

3. Are the respective roles and responsibilities of the GCMRC, AMWG, TWG, and SAB clearly articulated and adhered to?

4. Are there clear procedures in place to resolve disagreements between various GCDAMP entities?

5. How could the conflict resolution procedures of the GCDAMP be improved?

6. What decision support tools are available/appropriate to assist scientists and managers to improve the use of scientific knowledge in the resource management decision-making process?

7. How can Native American involvement in and input to GCDAMP be improved?

Strategic Science Questions

N/A

Project Goals/Tasks

1. Results of the 2007 AMP effectiveness workshop and other information (Science Advisors AMP review, roles report, etc.) would be used as the basis for developing follow-up workshop activities. The follow-up activities would focus on:

    - Providing refresher training on concepts and practical application of adaptive management and collaborative resource management. Training will be provided by experts in collaboration, partnerships, Native American involvement and/or conflict resolution

    - Addressing priority issues and action items from the 2007 AMP effectiveness workshop

    - Addressing other issues from the roles report and AMP effectiveness survey that were not addressed in the 2007 AMP effectiveness workshop

    Any follow-up workshops will be held in a centralized location and in conjunction with regularly scheduled AMWG/TWG meetings to minimize travel costs.

2. Follow-up workshop findings and recommendations developed will be reviewed by the AMWG and recommendations forwarded to the Secretary for consideration and implementation.

Links/Relationships to Other Projects

This project has implication for the overall operation of the GCDAMP. The workshop will also provide information directly relevant to the Decision Support System Feasibility Study planned for FY08.

Information Needs Addressed

GCDAMP research information needs (RINs): 12.3.1, 12.3.2, 12.3.3, 12.5.1, 12.5.2, 12.5.4, 12.7.1, 12.8.1, 12.9.2, 12.11.1

Products/Reports

1. Summary of workshop finding and recommendations

2. An action plan for implementing workshop finding and recommendations

In addition to products, the workshop is designed to produce important outcomes, including (1) increased understanding of the reality of practice of adaptive management in the Glen Canyon Adaptive Management Program, (2) improved relationships among the GCDAMP stakeholders that will result in more effective incorporation of scientific information into management decisions, (3) specific practical recommendations addressing key issues related to the effectiveness and use of science information, and (4) a specific action plan for implementing the recommendations.

Budget

Plan 12.P2.08	
AMP Effectiveness Workshop (FY07 – FY08)	
	Fiscal Year 2008

Program Management and Administration

Introduction

This chapter provides descriptions and budget information on GCMRC administration and management support services. GCMRC administration includes sections on administrative operations, program planning and management, AMWG/TWG participation, and the independent review process.

GCMRC Administration

The GCMRC will be administered by a core program management staff that includes the Center Chief and Deputy Chief and five expert program managers. In addition, they are supported by a fulltime secretary and budget analyst. The Southwest Biological Science Center provides timekeeping and travel support as well as an accounting technician who directs a minimum of 75% of her time to GCMRC related work.

In addition to their program management responsibilities, the Program Managers are also subject area experts in their respective fields on the CRE. It is important that GCMRC Program Managers and scientific staff maintain this expertise so they can provide high quality technical assistance in the form of expert analysis, opinion, and advice to the Chief, TWG, and AMWG, as requested. The Sociocultural Program Manager also functions as the Native American Coordinator. The Program Managers supervise additional technical and support staff, and act as project leads with their cooperators. DASA's activities will be carried out jointly with the Southwest Biological Science Center's (SBSC) Information Technology (IT) Department

ADM 12.A1.08: Administrative Operations

Start Date

Ongoing

End Date

Ongoing

Principal Investigator(s)

John Hamill, Chief, GCMRC

Geographic Scope

Glen Canyon Dam Adaptive Management Program

Need for Project

Effective management of the GCMRC program and the ability of its scientists and technicians to successfully fulfill their research obligations relies on their ability to effectively and efficiently perform their duties. It is necessary to have smooth running, transparent administrative operations that ensure the scientists' focus can remain on their research rather than on the administrative details involved with the payment of rent and utilities, timekeeping concerns, filing, and various other administrative topics. Administrative operations activities provide the oversight and management of facilities, burden and overhead; personnel issues; expenditure tracking; processing of and financial management of cooperative and interagency agreements; processing of contracts; timekeeping; bank card tracking and reconciliation; travel plans and voucher processing; and liaison activities between the USGS administrative groups (Flagstaff Science Center Administration, Western Region Budget and Fiscal Services and Contracting Offices, Headquarters in Reston, and the Biological Headquarters). In addition, this project is innately involved with the USGS nationwide budget tracking and reporting system known as BASIS+, that is used by the USGS Headquarters and Regional offices to make their annual reports to Congress as well as to respond to Congressional inquiries with turnaround times as short as 12 hours. (As part of the Glen Canyon Dam Adaptive Management Program, GCMRC administrators have been called upon to provide information of this type from the system on many occasions.)

Additional Information: In FY2008, standard overhead charges including facilities, space, general office supplies, costs for the USGS local network, Flagstaff Science Center support, and USGS regional services including contracting and personnel, as well as the salaries and general travel for the GCMRC secretary and budget analyst, have been moved to the Southwest Biological Science Center's overhead account. By doing this, GCMRC complies with regulations dictated by USGS headquarters and has identified a savings in administrative costs that has been applied to science projects. Only charges directly tied and traceable to GCMRC continue to be directly charged to the administrative operations account. These charges include GSA vehicle lease and maintenance; Interior vehicle gas, maintenance and replacement costs; funding for editorial support; safety and/or

other non-project specific mandated training; GCMRC non-project specific personnel support; telecommunications and shipping charges, etc.

Strategic Science Questions

N/A

Project Goals/Tasks

The goals of the project are to provide budgetary oversight and support to the Chief, Program Managers, and all employees of the GCMRC so that they may conduct their responsibilities in the most ethical, professional and efficient manner possible; to enable the employees to be unburdened, to the largest extent possible, by mundane administrative matters; and to support the USGS and GCMRC missions of conducting unbiased scientific research.

General Methods

General methods will include standard accounting procedures and regulatory and legal standards as required by the USGS and other Federal agencies with legal oversight. Quarterly updates to Program Managers will be provided as well as budgetary and other information provided upon request. The GCMRC will follow USGS guidelines as assigned for personnel, travel and other processes. Administrative personnel will focus on how to accomplish requests within Federal laws and regulations. The Administrative Officer for SBSC and the Budget Analyst for GCMRC will report annually to the AMWG/TWG on year-end projections and on the actual expenditures for the previous fiscal year.

Links/Relationships to Other Projects

This project is innately linked to all other projects. All project budgets are impacted by burden charges that are tracked and managed through Administrative Operations; all employees are required to track their time through a USGS personnel system; many Program Managers use cooperative or interagency agreements that are processed and tracked financially via administrative operations. Every project is given an account number and must be entered into and tracked, via its budget and its narrative, through the BASIS+ system. Administrative operations activities are tied to each project at the project’s earliest development.

Information Needs Addressed

N/A

Products/Reports

The Administrative Officer for SBSC and the Budget Analyst for GCMRC will produce a projection report (usually at the August AMWG meeting) for year end. In addition, they will present a report in actual expenditures for the previous fiscal year that will normally be presented at the March AMWG meeting.

Budget

ADM 12.A1.08	
Administrative Operations (Ongoing)	
	Fiscal Year 2008

ADM 12.A2.08: Program Planning and Management

Start Date

Ongoing

End Date

Ongoing

Principal Investigator(s)

John Hamill, Chief, GCMRC

Geographic Scope

Glen Canyon Dam Adaptive Management Program

Need for Project

Successful scientific research and reporting can be enhanced by strong and effective leadership that provides close working relationships between managers and employees. Good managers can apply knowledge as management actions that can enhance scientific research and imagination. In GCMRC, in addition to their program management responsibilities, the Program Managers are also subject area experts in their respective fields. It is important that GCMRC Program Managers and scientific staff maintain this expertise so they can provide high quality technical assistance in the form of expert analysis, opinion, and advice to the Chief, TWG, and AMWG, as requested. The Sociocultural Program Manager also functions as the Native American Coordinator. The Program Managers supervise additional technical and support staff, and act as project leads with their cooperators.

Additional Information: Beginning in FY06, in an effort to simplify distribution of program planning and management salaries and travel, the Program Manager salaries were assigned to this category exclusively. In FY2008, the full salary of the DASA Program Manager's salary is included in this line item. In addition, the Southwest Biological Science Center's Information Technologies Director salary has been removed and has been included in the general overhead account for the Cost Center, as have many of the charges described in Administrative Operations section. Travel expenses in support of the program, but separate from TWG and AMWG meeting travel, are also included. Salaries and travel costs for Program Managers, the Chief, and Deputy Chief are included in program planning and management budget.

Strategic Science Questions

N/A

Project Goals/Tasks

The GCMRC's goal is to deliver a comprehensive ecosystem science program over the next 5 years that is effective in responding to management needs articulated through the GCDAMP and by DOI. Productive, well-qualified personnel are critical to meeting achieving this goal.

General Methods

In order to provide strong leadership that provides a quality science program that is responsive to the needs of the GCDAMP, GCMRC will be administered by a core program management staff that includes the following key positions:

Center Chief

Establishes Center science policies and strategic direction and provides accountability for the GCMRC budget. Interfaces with USGS management, Secretary's GCDAMP Designee, and GCDAMP managers to assure that quality science is provided in a timely manner on priority issues identified by the GCDAMP leadership.

Deputy Chief

The Deputy Chief will be responsible for day-to-day management and supervision of the Physical Science and Modeling Program and assuring that integrated ecosystem science methods and procedures are utilized in science design and analysis.

Program Managers

Responsible for the timely execution of the science program within their program area; interaction with other program areas to ensure integrated ecosystem approaches, quality control of products and contractors/ cooperators; contract/agreement management; management of budget within their program area, and providing reports to GCDAMP work groups as needed. GCMRC activities now encompass five major program areas:

1. The **Physical Science and Modeling Program** conducts research and monitoring activities on physical elements of the Colorado River ecosystem including studies of sediment storage and transport in the regulated river, integrated downstream water quality monitoring and research. The program has been responsible for conducting several experimental high flow releases from Glen Canyon Dam (GCD) to conserve sediment resources for building beaches and improving habitat for native aquatic species in the Colorado River. More recent tasks have included development of a downstream temperature model for the ecosystem.

2. The **Data Acquisition, Storage, and Analysis (DASA) Program** that provides GIS, data quality control, data management, and library services support to all program areas. In addition, DASA oversees the GCMRC peer-review process.

3. The **Biological Program** that provides scientific information that supports the conservation of native species in the Grand Canyon and the Lees Ferry trout fishery. Elements of the program include the assessing the effects of GCD on fishery resources, characterizing the aquatic food base, evaluating terrestrial contributions to the aquatic food base, improving fish community monitoring, developing and testing of techniques to control nonnative fishes, evaluating terrestrial vegetation changes as a

result of dam operations, and water quality monitoring and modeling in Lake Powell and the Colorado River below GCD.

4. The **Cultural and Socioeconomic Program** that focuses on culturally significant sites and artifacts and recreation activities based in the Grand Canyon. The current focus is on development of comprehensive monitoring programs to assess the condition of the culturally significant sites affected by the operation of GCD.

5. The **Logistics Program** supports up to 40 river trips per year and coordinates research permit management for the Grand Canyon Monitoring and Research Center. The Logistics Program also provides survey support to various program and activities.

Links/Relationships to Other Projects

This project is linked by nature to all other projects, since each project must be managed by a Program Manager or the Chief.

Information Needs Addressed

N/A

Products/Reports

All products and reports produced by GCMRC are a result of this project.

Budget

ADM 12.A2.08	
Program Planning & Management (Ongoing)	
	Fiscal Year 2008

ADM 12.A3.08: AMWG/TWG Meeting Travel Funds

Start Date

Ongoing

End Date

Ongoing

Principal Investigator(s)

John Hamill, Chief, GCMRC

Geographic Scope

Glen Canyon Dam Adaptive Management Program

Need for Project

This project is an account to hold funds for travel expenses only for participation of employees who participate in AMWG and TWG meetings. Project related travel expenses are accounted for by projects, and administrative travel (e.g. general safety and security training) are planned under the Administrative Operations budget.

Strategic Science Questions

N/A

Project Goals/Tasks

To provide travel funds for employees who participate in AMWG and TWG meetings.

General Methods

Methods used are standard USGS travel authorizations and vouchers.

Links/Relationships to Other Projects

N/A

Information Needs Addressed

N/A

Products/Reports

N/A

Budget

ADM 12.A3.08	
AMWG/TWG Meeting Travel Funds (Ongoing)	
	Fiscal Year 2008

ADM 12.A4.08: Independent Reviews and Science Symposium

Start Date

Ongoing

End Date

Ongoing

Principal Investigator(s)

John Hamill, Chief, GCMRC

Geographic Scope

Glen Canyon Dam Adaptive Management Program

Need for Project

Independent external review is at the heart of GCMRC's approach to program management and implementation. Together with the competitive process, independent external peer review ensures the quality and objectivity of GCMRC's programs. Independent review panels are utilized to evaluate GCMRC's plans and activities. All proposals, reports, programs, etc., are subject to independent peer review according to GCMRC's peer-review protocols. Managing GCMRC's peer-review process requires 3–6 person-months, but requires no additional salary and is the responsibility of the Librarian/Review Coordinator. The Review Coordinator reports to the Chief directly, but works under the guidance of the DASA Coordinator for all non-review related activities.

Strategic Science Questions

N/A

Project Goals/Tasks

To increase the efficiency and quality of the science being developed by GCMRC and used by the AMWG and the Secretary, GCMRC will establish a peer-review process to ensure that all unsolicited, solicited, or in-house proposals and all draft reports received by GCMRC undergo independent, external peer review. Additionally, the Scientific Advisors Board will provide independent scientific oversight and technical advice to ensure that GCMRC science programs are efficient, unbiased, objective, and scientifically sound. The Scientific Advisors individually will be expected upon request, among other things, to review and comment on:

1. Results of ongoing and completed monitoring and research program activities, as well as any synthesis and assessment activities initiated by GCMRC

2. The appropriateness of GCMRC's RFPs, especially their responsiveness to management objectives

3. The protocols used in GCMRC sponsored scientific activities, including a 5-year review of GCMRC monitoring and research protocols

4. GCMRC's long-term monitoring plan

5. GCMRC's annual monitoring and research plans

6. GCMRC's annual budget proposals, to ensure that the science program is efficiently and effectively responding to AMWG goals (i.e., management objectives)

7. Any other program specific scientific and technical advice it is asked to address by the AMWG, the GCMRC, or the Secretary

General Methods

Peer Review

All of GCMRC's scientific activities undergo an independent, external peer review including all unsolicited, solicited, or in-house proposals. Similarly, all draft reports received by GCMRC undergo independent, external peer review. The peer-review protocols developed by GCMRC meet or exceed the standards articulated by the Secretary of the Interior for the Department of the Interior.

Peer review for proposals received by GCMRC in response to an RFP is conducted through a panel process, while peer review for unsolicited and in-house proposals, as well as project reports is conducted through the mail. In all cases, the reviewers are offered anonymity and the individual and panel reviews, where applicable, are provided to the PIs along with comments from GCMRC. In addition, GCMRC conducts PEPs to review and assess GCMRC's projects and methodologies. To date, PEPs have been held for remote sensing, physical, survey control, terrestrial and aquatic, cultural resources and the water quality program.

The GCMRC review process is handled by a report review coordinator to ensure that the peer-review process is conducted one-step removed from the GCMRC Program Managers to guard against any conflicts of interest – real or perceived. Strict conflict-of-interest guidelines are adhered to. GCMRC annually recruits new individuals to join the ranks of its peer reviewers and maintains a database of almost 500 potential reviewers, organized by area of expertise. GCMRC peer reviewers come from academia, Federal, State and Tribal government, non-governmental organizations, and the private sector. Reviewers are selected on the basis of their record of scientific accomplishment and expertise.

Science Advisors

The GCMRC works with a group of Science Advisors (SAs) as one of its independent review panels. The SAs are advisory and not a decision making body. It is an interdisciplinary group composed of scientists who are qualified, based on their record of publication in the peer-reviewed literature, or other demonstrable scientific achievements. An Executive Secretary leads the SAs and serves as the liaison officer to the AMWG and the GCMRC.

The SAs, together and individually, will be expected in FY08 to review and comment to the AMWG and GCMRC on: (1) GCMRC's annual work plan and budget proposal, (2) GCMRC's long-term monitoring and research plan (MRP), (3) the results of GCMRC's completed monitoring and research activities, (4) the results of any synthesis and assessment activities initiated by the GCMRC, and (5) any other activities (i.e., developing a

monitoring plan, enhancing opportunities for integrated science, and other program specific scientific advice) it is asked to address by the GCMRC Chief or the AMWG. The table below summarizes SA activities planned for FY08.

Requesting Group	Type Activity	Service Request	Completion Date and Months Required
TWG	Advisory service	Risk assessment of proposed experimental options and FY07–FY11 GCMRC/GCDAMP science program.	7/07; 10
GCMRC	Advisory service	Assist GCMRC in designing and implementing ecosystem science approaches in research and monitoring programs, experimental options, modeling, sampling designs, etc.	10/07; 12

Science Symposium

In the winter of 2008, GCMRC will host a science symposium to summarize recent research findings and recommendations since publication of the SCORE report in FY 2005. Reports will be provided on all major activities and finding that are relevant to high priority AMWG questions and related Strategic Science Questions. GCMRC will explore the interests in holding its science symposium in conjunction will similar meetings that are held for the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin, the San Juan River Recovery Implementation Program, and the Lower Colorado River Multi Species Habitat Conservation Plan to help promote increased technical dialogue and information exchange among these programs. Some of the costs for the Science Symposium will be recovered through a modest registration fee for participants.

Links/Relationships to Other Projects

N/A

Information Needs Addressed

N/A

Products/Reports

Final products will include final work plans that have undergone peer review (comments maintained on file at GCMRC) and peer-review comments on draft final reports produced related to projects included in the work plan (comments maintained on file at GCMRC).

Summarizes of papers presented at the 2008 Science Symposium will be published by GCMRC pursuant to USGS Fundamental Science Practices

Budget

ADM 12.A4.08	
Independent Reviews and 2008 Science Symposium (Ongoing)	
	Fiscal Year 2008

Note: The 2008 Science Symposium is included in the Independent Reviews Project.

ADM 12.A5.08: GCMRC Component of SBSC Systems Administration Support

Start Date

FY 2005

End Date

Ongoing

Principal Investigator(s)

John Hamill, Chief, GCMRC

Geographic Scope

Glen Canyon Dam Adaptive Management Program

Need for Project

The Information Technology (IT) Department of the SBSC supports a variety of technology needs of the GCMRC's various program areas: computer security, systems administration and procurement of new servers and computers, as well as Web site development and Web page maintenance. These support, development and maintenance services are cost shared between the GCMRC, the SBSC, and the IT Department is coordinated by the Center's Deputy Director so as to meet the IT needs of all four of the research stations.

Strategic Science Questions

N/A

Project Goals/Tasks

It is the IT Department's goal to ensure that GCMRC and all stations within SBSC are able to conduct scientific and administrative functions smoothly and with the least amount of disruption in service as possible. It is the IT Department's task to make IT functions as transparent as possible, to ensure each program has adequate current and future storage, and to provide excellent customer service at all times. IT maintains the security of GCMRC and SBSC networks up to current Federal standards and ensures all those who access the systems meet Federal security standards in order to protect personal information and scientific research that has not yet been released to the public. At the same time, the IT Department makes it their goal to ensure the public has full and easy access to publicly released data via GCMRC Web sites and works closely with the DASA program to make this possible.

General Methods

The IT Department follows all Federal, Department of the Interior, and USGS regulations regarding purchase of, access to, distribution and release of electronic information. Methods also include:

- Network environment - Computer interconnectivity is provided using TCP/IP network communication protocol running on a 1000baseT and 100baseT network media. Network traffic is arbitrated by 4 3COM switches and hubs operating at 100 Mbps and 1 Gbps.

- Internet connectivity – The GCMRC computer network is linked to the Internet through the Flagstaff Field Center GEOnet-3 router that provides a DS-3 (45 Mbps) virtual circuit to Menlo Park where it joins the U.S. Geological Survey's GEOnet network. Also located in Menlo Park is a network portal to the Internet operated by the U.S. Geological Survey and NASA through a peering partnership. GEOnet provides a secure Survey-wide networking environment that interconnects headquarter region, district, and field offices located throughout the United States.

- Intranet Web site – GCMRC's intranet offers a secure centralized medium for information exchange among GCMRC employees. Among things to be internally shared via the intranet are: standard operating procedures, personnel availability and contact info, vehicle and equipment loans, and an IT support system. The GCMRC intranet is served from a Windows 2000 Server utilizing ASP.

- Computer security – Network security is provided by firewalls, routers, system update server (SUS), systems management server (SMS), and antivirus (AV). Firewalls and routers are configured and maintained to restrict outside access to authorized systems. Operating systems (OS) are updated to minimize vulnerabilities using SUS that automates a central delivery system for patch management. Antivirus updates are downloaded from the web as released and pushed to all systems the same night.

- Desktop and servers - GCMRC's computing environment is based upon the PC platform, Microsoft Windows operating system, and Microsoft Office, office automation software. Systems maintenance is performed using a combination of warranty service, service contracts, and in-house service as needed to facilitate quick turnaround, minimize downtime, and reduce costs.

- System back-up and disaster recovery – System back-up and disaster recovery is accomplished using dual LTO tape drives in a 30-slot carriage with a capacity of 3 Tbytes. Tapes are stored locally in a fire vault and archival tapes are stored off-site. Server disks are configured to run either a raid-5 array or mirrored for redundancy.

- Troubleshooting and maintenance – Helpdesk support is provided as requested/required. Requests are received via the web, email and telephone. Support is tracked in a searchable database with solutions to facilitate prioritization and resolution.

- Assistance with GCMRC's data storage – Over 7 Tbytes of online disk storage is provided by multiple servers with SCSI disk arrays. Server disk arrays are hot swappable to minimize downtime. GCMRC also utilizes Networked Attached Storage (NAS) devices. These devices are IDE drives connected to a SCSI backplane. NAS units are used to provide bulk storage capacity at less expense.

Links/Relationships to Other Projects

All projects are integrated with IT support. Refer to the DASA section for more information on integration with these projects.

Information Needs Addressed

N/A

Products/Reports

The primary products and services of the SBSC Information Technology Department with respect to ongoing support of the GCMRC's needs are:

- Comprehensive and fully functional Web site development and maintenance, with access to all non-sensitive digital data and information relating to the effects of dam operations on the CRE. Non-digital data and information will be cataloged electronically with instructions on how to obtain it.

- Coordination with GCMRC's DASA to ensure and support a comprehensive and fully functional library containing all hard copy and digital media containing data and information relating to the effects of dam operations on the CRE cataloged and accessible. Sensitive and non-releasable data and information will be archived and secured separately from releasable data and information.

- Fully functional and integrated computing environment.

- Web and FTP Services – The GCMRC Web site and FTP site serve to make the mission and findings of GCMRC accessible to the public. The sites offer our updated work plan, descriptions of our program areas, and various interactive stores of data including our Internet Map Server and our online library.

- Assistance and support of online discussion forums – GCMRC hosts online discussions forums for the AMWG, GCMRC, and the U.S. Geological Survey LiDAR discussion group. These forums provide a widely accessible medium for informal discussions and announcements relating to the respective topics.

Budget

ADM 12.A5.08	
GCMRC Component of SBSC Systems Administration Support (FY05 – Ongoing)	
	Fiscal Year 2008

Note: The 2008 Science Symposium is included in the Independent Reviews Project.

APPENDIX A. Key Science Questions Addressed in the FY07–FY11 Science Program

AMWG Priority 1: Why are the humpback chub not thriving, and what can we do about it? How many humpback chub are there and how are they doing? (GCDAMP goal 2)

Key Strategic Science Questions

1. To what extent are adult populations of native fish controlled by production of young fish from tributaries, spawning and incubation in the main stem, survival of young-of-year (YoY) and juvenile stages in the main stem, or by changes in growth and maturation in the adult population as influenced by main stem conditions? [FY06–FY11]

2. Does a decrease in the abundance of RBT and other cold and warm water nonnatives in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile humpback chub to the adult population? [FY06–FY11]

3. Do RBT immigrate from Glen to Marble and eastern Grand Canyons, and, if so, during what life stages? To what extent do Glen Canyon immigrants support the population in Marble and eastern Grand Canyons? [FY07–FY11]

4. Can long-term decreases in abundance RBT in Marble and eastern Grand Canyons be sustained with a reduced level of effort of mechanical removal or will recolonization from tributaries and from downstream and upstream of the removal reach require that mechanical removal be an ongoing management action? This question also applies to future removal programs targeting other nonnative species. [FY07–FY11]

5. What are the important pathways, and the rate of flux among them, that link lower trophic levels with fish and how will they link to dam operations? [FY06–FY09]

6. Are trends in the abundance of fish populations, or indicators from fish such as growth, condition, and body composition (e.g., lipids), correlated with patterns in invertebrate flux? [FY06–FY09].

7. Which tributary and mainstem habitats are most important to native fishes and how can these habitats best be made useable and maintained? [FY08–FY09].

8. How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling? [FY07–FY11].

AMWG Priority 2: Which cultural resources, including Traditional Cultural Properties (TCP), are within the Area of Potential Effect, which should we treat, and how do we best protect them? What is the status and trends of cultural resources and what are the agents of deterioration? (GCDAMP goal 11).

Key Strategic Science Questions

1. Do dam controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how? [FY07–FY11]

2. How do flows impact old high-water zone terraces in the CRE (where the majority of archaeological sites occur), and what kinds of important information about the historical ecology and human history of the CRE are being lost due to ongoing erosion of the Holocene sedimentary deposits? [FY04–FY11]

3. If dam controlled flows are contributing to (influencing rates of) archaeological site/TCP erosion, what are the optimal flows for minimizing future impacts to historic properties? [FY09–FY11]

4. How effective are various treatments (e.g., check dams, vegetation management, etc.) in slowing rates of erosion at archaeological sites over the long term? [FY06–FY11]

5. What are the TCPs in the CRE, and where are they located? [FY06–FY11]

6. How can tribal values/data/analyses be appropriately incorporated into a science-driven adaptive management process in order to evaluate the effects of flow operations and management actions on TCPs? [FY06–FY08]

7. Are dam controlled flows affecting TCPs and other tribally valued resources in the CRE, and, if so, in what respects are they being affected, and are those effects considered positive or negative by the tribes who value these resources? [FY06–FY11]

AMWG Priority 3: What is the best flow regime? (GCDAMP goals 1–11)

Key Strategic Science Questions

1. Is there a “Flow-Only” operation (i.e. a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal time scales? [FY08–FY11]

2. To what extent could predation impacts by nonnative fish be mitigated by higher turbidities or dam controlled high flow releases? [FY07–FY08]

3. What are the hydropower replacements costs of the MLFF (annually, since 1996)? [FY07–FY08]

4. What are the projected hydropower costs associated with the various alternative flow regimes being discussed for future experimental science (as defined in the next phase experimental design)? [FY06–FY07]

5. How is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations? [FY06–FY08]

6. What GCD operations (ramping rates, daily flow range, etc.) maximize trout fishing opportunities and catchability? [FY07–FY08]

7. How do dam controlled flows affect visitors' recreational experiences, and what is/are the optimal flows for maintaining a high quality recreational experience in the CRE? [FY07–FY08]

8. What are the drivers for recreational experiences in the CRE, and how important are flows relative to other drivers in shaping recreational experience outcomes? [FY07–FY09]

9. How do varying flows positively or negatively affect campsite attributes that are important to visitor experience? [FY09–FY11]

10. How can safety and navigability be reliably measured relative to flows? [FY07–FY08]

11. How do varying flows positively or negatively affect visitor safety, health, and navigability of the rapids? [FY07–FY09]

12. How do varying flows regimes positively or negatively affect group encounter rates, campsite competition, and other social parameters that are known to be important variables of visitor experience? [FY07–FY09]

AMWG Priority 4: What is the impact of sediment loss and what should we do about it? (GCDAMP goal 8)

Key Strategic Science Questions

1. Is there a "Flow-Only" operation (i.e. a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal time scales? (FY08–FY11)

2. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish? Does the long-term benefit of increasing these habitats outweigh short-term potential costs (displacement and possibly mortality of young humpback chub) associated with high flows? [FY07–FY11]

AMWG Priority 5: What will happen when we test or implement the Temperature Control Device (TCD)? How should it be operated? Are safeguards needed for management? (GCDAMP goals 1–4 and 7–10)

Strategic Science Questions

1. How do dam release temperatures, flows (average and fluctuating component), meteorology, canyon orientation and geometry, and reach morphology interact to determine mainstem and nearshore water temperatures throughout the CRE? [FY06–FY08]

2. How is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations? [FY06–FY08]

3. To what extent do temperature and fluctuations in flow limit spawning and incubation success for native fish? [FY03–FY08]

4. What is the relative importance of increased water temperature, shoreline stability, and food availability on the survival and growth of YoY and juvenile native fish? [FY03–FY08]

5. Will increased water temperatures increase the incidence of Asian Tapeworm in humpback chub or the magnitude of infestation, and if so, what is the impact on survival and growth rates? [FY03–FY08]

6. Do the potential benefits of improved rearing habitat (warmer, more stable, more backwater and vegetated shorelines, more food) outweigh negative impacts due to increases in nonnative fish abundance? [FY07–FY11]

7. How do warmer releases affect viability and productivity of native/nonnative vegetation? [FY07–FY11]

APPENDIX B. GCDAMP Fiscal Year 2008 Budget Explanatory Material

The draft fiscal year 2008 Glen Canyon Dam Adaptive Management Program (GCDAMP) budget, which includes budgets for GCDAMP activities preformed by the Bureau of Reclamation and the U.S. Geological Survey (USGS) Grand Canyon Monitoring and Research Center, is attached separately. The following table explains the information found in various columns of the budget document. Following the table is an explanation of USGS policy on cost-recovery accounting and cost share.

Table A.1. Explanation of information found in columns of draft fiscal year 2008 Glen Canyon Dam Adaptive Management Program (GCDAMP) budget.

Column	Title	Key
A	**GCMRC Project ID**	**Col 1–3 Program Area** **BIO: Biology** **PHY: Physical Science** **REC: Recreation** **HYD: Hydropower** **CUL: Cultural** **DASA: Data Acquisition, Storage, and Analysis** **SUP: Support** **ADM: Administration** **PLA: Planning** **Col 4–5: GCDAMP Goal Number** **Col 6–7: Project Number** **Col 8–9: Fiscal Year**
B	**Status**	**O: Ongoing** **N: New** **C Complete**
C	**Category**	**R&D: Research and Development** **EXP: Experimental** **CM: Core Monitoring** **HCA: Humpback Chub Action** **DASA: Data Acquisition, Storage, and Analysis** **SUP: Support** **ADM: Administration** **PLA: Planning**
D	**Project Description**	**Project Title (Start Date-End Date)**
F	**Est FY08**	**Estimated FY08 Cost of an Ongoing Project**

Remaining columns are self explanatory (we hope)

Explanation of USGS Policy on Cost Share

In FY 2003, the USGS began full-cost recovery accounting and instituted a DOI customer rate of 15% against all DOI agency reimbursable funding. In FY 2007, the customer rate is estimated at the 15% DOI customer rate with an additional 2% added to achieve the required additional facilities costs. The DOI customer rate was established by the USGS Bureau Headquarters and determined to be significantly lower than the "full" burden rate that varies annually and includes facilities and the Cost Center and the Bureau level burdens. In addition to the above rates, a special "pass through" rate of 6% was also instated. As a transitional aid to GCMRC, which had received under a previous administration the guarantee that USGS would not charge the power revenue funds any burden, the Bureau allowed the entire GCMRC power revenue budget to be charged only the 6% special rate (3% was retained by the Cost Center and 3% by Headquarters) for FY 2003 only.

In FY 2004, USGS Headquarters approved the special rate of 6% for only a portion of GCMRC's power revenue funding. This rate was applied to approximately $2 million of funding that went directly to GCMRC cooperators. The balance of power revenue funds were charged the full DOI customer rate of 15%. As a part of the full cost recovery policy, the USGS established a process referred to as "cost share" as a means of handling a limited electronic financial system.

Cost Share is the funding that "covers" the balance of the full burden rate minus the DOI customer rate. In most cases, reimbursable funding from non-DOI agencies is charged the full burden rate. In FY 2004, the full burden rate for GCMRC was approximately 30%. The difference between the full rate of 30% and the DOI Customer rate of 15% equals 15% (all percentages are approximate). In FY 2004 the cost share funding requirement for all DOI agency reimbursable dollars received by GCMRC equaled almost $1 million. USGS policy requires cost share funding be from appropriated dollars only, and those funds are also charged the Cost Center burden rate. In essence, the $1 million appropriation provided by USGS to GCMRC in FY 2004 had the effect of not adding funding, but merely filling the holes created by the cost share policy.

In FY 2005 and FY 2006 the USGS appropriation requested for GCMRC (also $1 million each fiscal year) was used for cost share funding. However, information has been forwarded to the GCMRC that the required DOI cost share funds will be provided by the USGS Headquarters, so as to continue allowing for the reduced customer rate to apply to the GCMRC science program in FY07. Per the full cost accounting policy and the requirement that cost share dollars be appropriated dollars only, the effect of these appropriations is entirely transparent and does not add funding to the GCDAMP. The issue relating to how these cost share funds are derived in the future is a major area of concern for the GCMRC science program.

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