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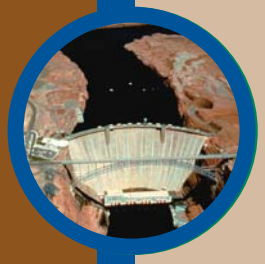
Prepared by the Grand Canyon Monitoring and Research Center

Developed in cooperation with the Glen Canyon Dam Adaptive Management Program

Strategic Science Plan to Support Glen Canyon Dam Adaptive Management Program, Fiscal Years 2007–11



Draft for AMWG Review
October 27, 2006

U.S. Department of the Interior
U.S. Geological Survey

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Strategic Science Plan to Support the Glen Canyon Dam Adaptive Management Program, Fiscal Years 2007–11

Introduction and Background

This strategic science plan (SSP) identifies strategies to be pursued by the U.S. Geological Survey's (USGS) Grand Canyon Monitoring and Research Center (GCMRC) during the next 5 years to provide credible, objective scientific information to the Glen Canyon Dam Adaptive Management Program (GCDAMP). Specifically, scientific information will be developed regarding (1) the effects of the operation of Glen Canyon Dam and other related factors on resources of the Colorado River ecosystem (the Colorado River corridor from the dam to Lake Mead; CRE), using an ecosystem approach, and (2) flow and nonflow measures to mitigate adverse effects on CRE resources caused by dam operations. This strategic science plan will be carried out by the GCMRC in cooperation with participants of the GCDAMP.

The Glen Canyon Dam Adaptive Management Program was established in 1996 by the Secretary of the Interior to implement the Grand Canyon Protection Act of 1992, the 1995 Operation of Glen Canyon Dam Final Environmental Impact Statement, and the 1996 Record of Decision. Adaptive management in Grand Canyon was envisioned as a new paradigm for addressing the complex environmental problems related to the operation of Glen Canyon Dam through the dynamic interplay of stakeholder collaboration, resources management, and scientific research. As a result, the GCDAMP consists of five major components (fig. 1):

- The **Adaptive Management Work Group** (AMWG) is a Federal Advisory Committee established to facilitate the implementation of the GCDAMP, which is composed of 25 stakeholders and the Secretary of the Interior's Designee. After careful review, the AMWG makes recommendations to the Secretary of the Interior on how to best alter dam operations or other management actions in order to fulfill the U.S. Department of the Interior's obligations under the Grand Canyon Protection Act.
- The **Secretary of the Interior's Designee** serves as the chair of the AMWG and provides a direct link between the AMWG and the Secretary of the Interior.
- The **Technical Work Group** (TWG) translates the AMWG's policies and goals into information needs, provides questions that serve as the basis for long-term monitoring and research activities, and conveys research results to AMWG members.
- The **Grand Canyon Monitoring and Research Center** provides credible, objective scientific information on the effects of the operation of Glen Canyon Dam and related factors on natural, cultural, and recreational resources along the Colorado River from Glen Canyon Dam to Lake Mead (see table 1 for specific responsibilities).
- The **Independent Review Panels** provide independent assessments of proposals and accomplishments to ensure scientific objectivity and credibility. For example, a formal group of Science Advisors consisting of academic experts in fields germane to studies within the scope of the GCDAMP serves as an independent review panel.

Adaptive Management

The GCDAMP is based on an adaptive environmental assessment and management (AEAM) approach to natural resources management (Holling, 1978; Walters, 1986), now popularly called "adaptive management." The approach assumes that managed natural resources will always change, that scientific understanding of ecosystems is constantly improving, and that it is incumbent on natural resource managers to use the best currently available information to make decisions. AEAM brings together the strengths of different scientific disciplines to address the information needs of resource managers, and it encourages scientists and managers to work collaboratively to use scientific information in the management process.

AEAM consists of two related parts—adaptive assessment and adaptive management. The assessment phase investigates how ecological systems work and evaluates possible alternative actions that managers can implement to achieve desired goals. The management phase involves learning by doing and testing, which may include the monitoring of sys-

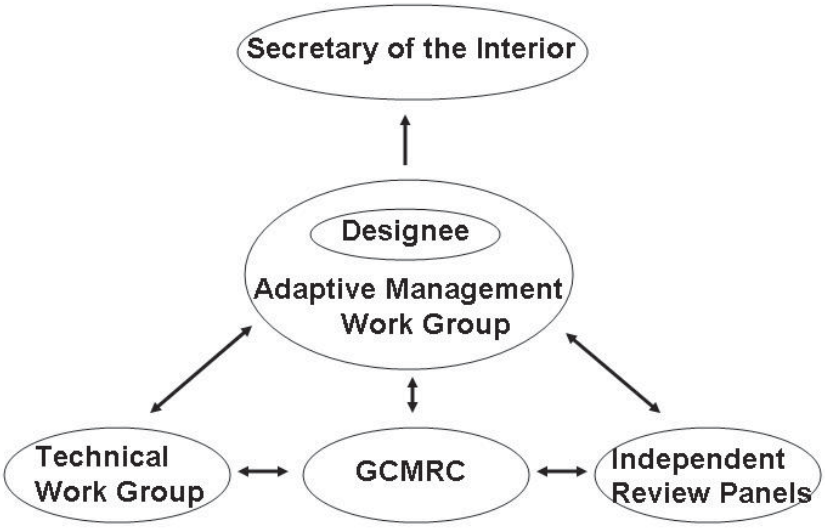

Figure 1. Major components of the Glen Canyon Dam Adaptive Management Program.

tem responses to natural changes (passive adaptive management) or by deliberate manipulation of key processes (active adaptive management). Adaptive management acknowledges that policies must satisfy social objectives, but they also need to be flexible enough to adapt to both changing understandings and alterations in managed systems. Managers who are actively using an AEAM approach will learn more about how a natural system works and how their actions change that system, which will allow them to better manage in complex and uncertain environments.

This strategic science plan is based on a specific AEAM approach articulated in the draft GCDAMP strategic plan, which includes:

1. The development of models to reveal the potential effects of policies, activities, or practices that are being considered for implementation;
2. The formulation of questions as testable hypotheses regarding the expected responses or linkages of the Colorado River ecosystem to dam operations and other management actions;
3. The execution of experiments to test hypotheses and answer questions;
4. The implementation of management activities to reveal the accuracy or completeness of earlier predictions through monitoring and evaluation of results; and
5. The incorporation of new knowledge and information produced through experimentation into management discussions and recommendations to the Secretary of the Interior.

Science Planning Process

The GCDAMP has adopted a science planning process to develop a credible, objective science program that is responsive to the goals and priority needs identified by the AMWG. The AMWG specified 12 goals that provide general guidance for planning, monitoring, and research efforts (table 2). In August 2004, the AMWG reviewed these goals and identified priority questions to help guide the GCDAMP science program. The AMWG identified five priority questions:

1. **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?
2. **AMWG Priority 2**: Which cultural resources, including traditional cultural properties, 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?
3. **AMWG Priority 3**: What is the best flow regime?
4. **AMWG Priority 4**: What is the impact of sediment loss and what should we do about it?
5. **AMWG Priority 5**: What will happen when a temperature control device is tested or implemented? How should it be operated? Are safeguards needed for management?

The GCMRC will use these questions as the primary, but not exclusive, basis for designing the science program to be

Table 1. Roles and responsibilities of the Grand Canyon Monitoring and Research Center (GCMRC).

1.	Advocate quality, objective science and the use of that science in the adaptive management decision process
2.	Provide scientific information for all resources of concern identified in the Operation of Glen Canyon Dam Final Environmental Impact Statement
3.	Support the Secretary of the Interior's Designee and the Adaptive Management Work Group (AMWG) in a technical advisory role
4.	Develop research designs and proposals for implementing monitoring and research activities in support of information needs identified by the AMWG
5.	Coordinate review of monitoring and research activities with independent review panels
6.	Coordinate, prepare, and distribute technical reports and documentation for review and publication as final products
7.	Provide regular reports to the AMWG and Technical Work Group (TWG) on new scientific findings and their application to the Glen Canyon Dam Adaptive Management Program (GCDAMP); prepare and forward technical management recommendations and annual reports to the TWG
8.	Manage all data collected as part of the GCDAMP and serve as a repository for data and information about the effects of Glen Canyon Dam operations and other related factors on the downstream resources of the Colorado River ecosystem
9.	Administer research proposals through a competitive contract process, as appropriate
10.	Manage GCMRC finances and personnel efficiently and effectively

implemented during the next 5 years. Other sources of information that will be considered include:

- AMWG management objectives and associated information needs, including core monitoring information needs;
- Protocol evaluation panel recommendations;
- Knowledge assessment report findings and recommendations;
- U.S. Fish and Wildlife Service biological opinion requirements related to the operation of Glen Canyon Dam; and
- National Historic Preservation Act requirements.

Generally, the GCMRC will propose at least one science activity for each GCDAMP goal (table 2) in its work plan to create a balanced adaptive management program and to ensure that all key resources are addressed by the science program.

Science Planning Documents

The GCMRC will design and implement the GCDAMP science program in coordination and cooperation with the various GCDAMP stakeholders. Interaction between the GCMRC and GCDAMP participants shall occur primarily in the context of four key documents:

1. The final draft GCDAMP strategic plan (AMPSP) is a long-term plan drafted by GCDAMP participants in cooperation with the GCMRC in August 2001 that identifies the AMWG's vision, mission, principles, goals, management objectives, information needs, and management actions (http://www.usbr.gov/uc/rm/amp/strategic_plan.html).
2. The GCMRC strategic science plan (this document) identifies strategies to be used during the next 5 years for providing science information responsive to the goals, management objectives, and priority questions of GCDAMP participants. The strategic science plan has been designed to be consistent with the AMPSP.
3. The GCMRC monitoring and research plan (MRP) specifies research and monitoring activities consistent with the strategies and priorities established in the SSP. Currently in draft, the MRP identifies the objectives and strategic science question(s) associated with each core monitoring, research and development, long-term experimental activity.
4. The GCMRC biennial work plan (BWP) identifies the scope, objectives, and budget for monitoring and research activities planned for a 2-year period. When completed, the biennial work plan will be consistent with the MRP. A transitional annual work plan (AWP) was developed for fiscal year (FY) 2007.

Figure 2 depicts the flow of information in the science planning and implementation process. Annually, the 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 objec-

Table 2. Glen Canyon Dam Adaptive Management Program (GCDAMP) goals as identified in the draft strategic plan.

1.	Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels
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 habitats
3.	Restore populations of extirpated species, as feasible and advisable
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
5.	Maintain or attain viable populations of Kanab ambersnail
6.	Protect or improve the biotic riparian and spring communities, including threatened and endangered species and their critical habitat
7.	Establish water temperature, quality, and flow dynamics to achieve the GCDAMP ecosystem goals
8.	Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve the GCDAMP ecosystem goals
9.	Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of the GCDAMP ecosystem goals
10.	Maintain power production capacity and energy generation, and increase where feasible and advisable, within the framework of the GCDAMP ecosystem goals
11.	Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations
12.	Maintain a high-quality monitoring, research, and adaptive management program

tives. At 5-year intervals, the GCMRC shall formally synthesize new scientific information and knowledge in updated versions of The State of the Colorado River Ecosystem in the Grand Canyon (SCORE) report (Gloss and others, 2005), knowledge assessment report (Melis and others, 2006), and other reports, as appropriate. Priority information needs and science questions will be evaluated by scientists and managers to determine what program revisions are needed. Planning documents, including the SSP and the MRP, will also be revised to reflect program updates.

GCMRC science planning will be most effective if it is conducted in conjunction with a periodic review of the GCDAMP strategic plan, including priority goals, information needs, management objectives, and management actions/treatments. Completing concurrent reviews will help ensure the science program is properly aligned with current management objectives and priorities.

Science Strategies

This strategic science plan is based on the adaptive management paradigm, wherein new science information is continually cycled into application by managers, and outcomes are monitored by scientists and managers for effectiveness. This adaptive management process requires highly focused applied science projects that address specific management information needs. Consistent with the adaptive management paradigm, the GCMRC's science strategy will emphasize four elements:

- Interdisciplinary, integrated river science;
- Building bridges between science and management;
- Strategic science questions to address the AMWG's priority goals and questions; and
- Critical research and monitoring needs outside the scope of the GCDAMP.

Interdisciplinary, Integrated River Science

The GCMRC will increase its emphasis on employing an interdisciplinary, integrated science approach over the next 5 years. An interdisciplinary, integrated approach can better support the AMWG's goals for how to best manage and sustain competing resource values to benefit both humans and the natural ecosystems to which humans belong. This means that single resources (and research related to them) will not be studied in isolation from other resources or from the sociocultural context. Interdisciplinary, integrated river science will be aimed at understanding and, ultimately, predicting how resources respond to human activities, outside forces, and internal natural ecosystem drivers (e.g., floods, drought, plankton blooms, etc.). Understanding will come through core monitoring, research and development, and long-term experimental activities. Prediction will be developed from a synthesis of findings in a quantitative modeling framework.

In 1998, Walters and others (2000) conducted an adaptive environmental assessment and management workshop to assist Grand Canyon scientists and managers to develop a conceptual model of the Colorado River ecosystem affected by Glen Canyon Dam operations. The model proved to be useful tool for identifying knowledge gaps and predicting the response of some ecosystem components to policy change. However, the lack of available data for some resources and resource responses limited the model's effectiveness in several key areas, including long-term sediment storage, fisheries responses to habitat restoration, and socioeconomic effects. Several improvements to the model have been suggested to increase its use in science-planning and management processes. Suggested improvements include making the model more user friendly, ensuring that the model provides information that is relevant to each high-priority AMWG goal and question, and incorporating advanced statistical and mathematical methods.

In 2007, the GCMRC will work with the Science Advisors to identify and evaluate opportunities for incorporating an interdisciplinary, integrated ecosystem science and modeling approach into the current science program, including the refinement and use of conceptual and predictive ecosystem models and decision-support tools. The feasibility of various approaches should be assessed based on their ability to satisfy the information needs of resource managers; usefulness for designing an integrated, interdisciplinary science program for the GCDAMP; and implementation costs.

Building Bridges between Science and Management

The GCMRC's ability to design studies that will produce relevant scientific information depends on how well the GCDAMP participants clearly define and agree on resource goals, management objectives, and desired outcomes. To be successful, GCMRC scientists and GCDAMP participants must work together as partners—partners who recognize each other as having distinct but complementary roles. Individual roles and responsibilities are generally outlined in table 3. A more complete discussion of the roles and responsibilities of various GCDAMP entities, including the GCMRC, is presented in the report of the Roles Ad Hoc Group of the GCDAMP (2006).

The success of the GCDAMP is dependent on not only the GCMRC's ability to produce scientific information that is relevant to management needs, but also the effective and timely use of that information by managers in the decision-making process. The challenge for scientists is to synthesize large amounts of diverse and often highly technical data into a form that is relevant to a decision that has implications for multiple resources in different areas and time frames. A clear example of this challenge is the issue of how to operate Glen Canyon Dam. Over the past decade, there have been great advances in the development and application of a suite of decision-support tools to assist scientists and managers to understand the interrelationships, data uncertainty, and relative influence of scientific knowledge on resource management decisions.

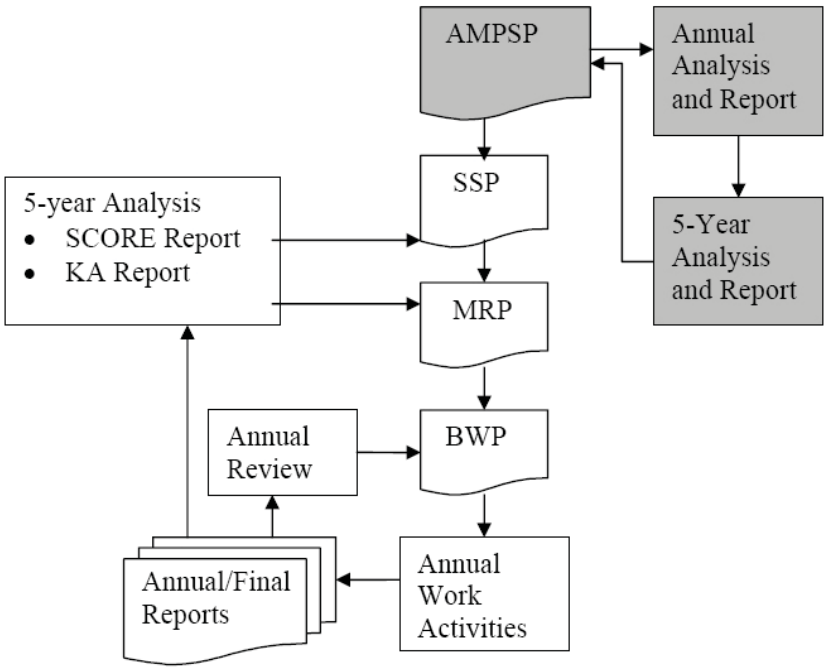

Figure 2. Collaborative science planning and implementation process. The Glen Canyon Dam Adaptive Management Program and the U.S. Department of the Interior have lead responsibility for the shaded boxes. The Grand Canyon Monitoring and Research Center has lead responsibility for the boxes that are not shaded.

Table 3. Lead roles of the Grand Canyon Monitoring and Research Center (GCMRC) and the Glen Canyon Dam Adaptive Management Program (GCDAMP).

Lead Roles of the GCMRC	Lead Roles of the GCDAMP
Develop and revise the GCMRC strategic science plan, monitoring and research plan, and biennial work plan	Develop, revise, and finalize the GCDAMP strategic plan, which specifies program goals, information needs, priorities, and management objectives
Develop and update the knowledge assessment and The State of the Colorado River Ecosystem in Grand Canyon (SCORE) reports	Develop and revise operations protocols to improve the effectiveness of the GCDAMP
Advise the Technical Work Group and Adaptive Management Work Group on technical program needs, experimental options, and management treatments	Review and comment on proposed science activities and budgets; provide recommendations to the Secretary of the Interior
Develop research designs, proposals, and treatment options; implement and manage the science program	Provide clear and timely management direction
Evaluate the scientific basis of proposed management actions and treatments	Identify and implement management actions and treatments

The GCMRC proposes a collaborative effort among scientists and GCDAMP participants to develop and facilitate an independent assessment of how to better integrate the use of scientific information into the GCDAMP process. The assessment will address (1) the feasibility of developing and making use of decision-support tools to facilitate integration of scientific information in the science-planning and GCDAMP recommendation processes, including resource trade-off assessments, and (2) strategies and approaches for more effectively addressing the value-based conflicts reflected by the diverse interests in the GCDAMP. Pilot approaches developed through this process will be implemented and tested during the FYs 2007–11 program period.

Addressing Priority Goals and Questions

The GCMRC science program will be driven primarily by AMWG priority questions and the associated key strategic science questions identified in the knowledge assessment report (Melis and others, 2006), which are presented in the following section. Addressing these key strategic science questions will result in information directly related to AMWG priorities and reduce the uncertainties associated with various flow and nonflow treatments being considered by the GCDAMP.

The strategic science questions will be addressed through core monitoring, research and development, and long-term experimental activities using an interdisciplinary, integrated science approach, where appropriate. Specific monitoring and research activities will be defined in the MRP and the BWP and based on the knowledge assessment, core monitoring information needs, research information needs, and other relevant information. The MRP and the BWP will identify each activity's objectives, methods, outcomes, and costs by fiscal year.

When appropriate, the GCMRC will coordinate and collaborate with other relevant research activities being conducted by agencies and institutions to ensure a more coordinated and cost-effective ecosystem approach.

AMWG Priority Questions and Related Strategic Science Questions

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 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? [FY06–FY11]
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? [FY06–FY11]
3. Do rainbow trout 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 the 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. [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 usable 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 turbidity or dam-controlled high-flow releases? [FY07–FY08]

3. What are the hydropower replacement costs of the modified low fluctuating flow (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–FY09]

6. What Glen Canyon Dam 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)

Key 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]

Other Critical Research and Monitoring Needs

This section focuses on the critical need in the GCDAMP to address issues outside the CRE that impact the GCDAMP's mission and goals. The GCMRC is currently constrained from using GCDAMP funds to evaluate some potentially significant external threats to CRE resources. For example, the largest aggregation of humpback chub in the CRE is directly dependent on the quality of water leaving the Little Colorado River (LCR). However, LCR water quality is evaluated on an infrequent basis and then only in the first few miles of its confluence with the Colorado River. There is currently no means of identifying changes in LCR water quality and quantity resulting from upstream diversions, pollution, or catastrophic hazardous material spills. A second concern is the quality of the water released from Lake Powell. For example, the water-quality characteristics and dynamics of Lake Powell have major implications for the design and operation of the proposed temperature control device that will allow for regulating the temperature and other water-quality characteristics of releases from Glen Canyon Dam. While extensive physical and biological data on Lake Powell water quality have been collected for more than two decades, the data have not been synthesized or subjected to extensive analysis or advanced modeling. A synthesis of historical Lake Powell data is needed to identify trends in water quality and their relationship to dam operations, basin hydrology, and climate variability. These assessments could significantly advance knowledge of potential future water quality in Lake Powell and the appropriate design and operation of a temperature control device.

To be successful, the GCDAMP needs to ensure that key external factors that could affect the attainment of GCDAMP goals are addressed. To this end, the GCMRC proposes (1) to work closely with the AMWG and the U.S. Department of the Interior to help develop an endangered fish recovery program for the lower Colorado River Basin/Grand Canyon, (2) to

evaluate and report on key external issues like those identified above that could affect attainment of GCDAMP goals, and (3) to work with GCDAMP participants and other relevant parties to secure funding to initiate science activities to address key issues that pose the highest risk or opportunity.

Administration and Budget

GCMRC Administration and Staffing

In the next 5 years, the GCMRC's goal is to deliver a comprehensive ecosystem science program that effectively responds to management needs. Effectiveness will be measured by science and management accomplishments that enhance CRE resource conditions and create a better understanding of the cause-and-effect relationship between dam operations and resource conditions. Improving science administration is essential to meeting the increasing need for a broader, more comprehensive ecosystem science program in a flat budget environment. Improving science administration will require significant effort in several areas, including science planning, personnel structure, goal and objective setting, collaboration and partnerships, and research design focused on priority information needs and cost effectiveness.

Productive, well-qualified personnel are critical to creating an effective ecosystem science program. In recognition of this fact, efforts have been made to restructure personnel responsibilities at the GCMRC to maximize existing management and science skills. Contractors and cooperators will be used to conduct a large amount of the field work, and they will work collaboratively with GCMRC on data analysis and synthesis and the publication of findings. GCMRC scientists will be engaged in the implementation of field research and monitoring when in-house staff members with the appropriate expertise are available and their use is cost effective. In every case, the GCMRC will hold its own work to the same level of rigorous outside peer review as all others.

The core GCMRC staff includes the following key positions:

Center Chief

The Center Chief establishes GCMRC's science policies and strategic direction and provides budget accountability. The Chief assures that science managers, contract and budget officers, logistics specialists, external and resident scientists, and other personnel plan and implement timely science activities that respond to GCDAMP priority information needs. The Chief also interfaces with USGS management, the Secretary of the Interior's Designee, and GCDAMP participants to assure that quality science is provided in a timely manner on priority issues identified by GCDAMP leadership.

Deputy Chief

The Deputy Chief is responsible for the day-to-day management and supervision of the science program, assuring that integrated ecosystem science methods and procedures are used in science design and analysis. This position also has responsibility for monitoring peer-review processes, tracking science project performance, and reporting program outcomes to assure timely responses to GCDAMP information needs.

Program Managers

Individual Program Managers are responsible for the timely execution of the science activities within their program area, interaction with other program areas to ensure the development and use of integrated ecosystem approaches, quality control of products and contractors/cooperators, contract/agreement management, budget management for their program area, and the provision of 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 and integrated downstream water-quality monitoring and research. The program has been responsible for conducting several experimental high-flow releases from Glen Canyon Dam to conserve sediment resources for building beaches, preserving archaeological sites, and improving habitat for native aquatic species in the Colorado River. More recently, the program developed a downstream temperature model for the ecosystem.

2. The **Data Acquisition, Storage, and Analysis (DASA) Program** provides GIS, data quality control, data management, and library services to all program areas. In addition, DASA coordinates the GCMRC peer-review process.

3. The **Biological Program** provides scientific information that supports the maintenance of the Lees Ferry trout fishery and the conservation of native species in the Grand Canyon. Elements of the program include assessing the effects of Glen Canyon Dam operations 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 Glen Canyon Dam.

4. The **Cultural and Socioeconomic Program** focuses on evaluating the effects of Glen Canyon Dam operations on

culturally significant sites and recreation activities based in the Grand Canyon. The program also evaluates the socioeconomic implications of dam operations and treatments. Currently, the program is working on the development of comprehensive monitoring activities to assess the condition of the culturally significant sites affected by the operation of Glen Canyon Dam.

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.

The GCMRC will rely on the USGS Southwest Biological Science Center (SBSC), the parent organization of GCMRC within the USGS, for administrative, budget, and contracting services; information technology support; and policy direction. The GCMRC will also work with the SBSC to reduce shared costs and overhead burden assessed by the USGS on GCDAMP funds.

As part of the strategy to improve science administration effectiveness, the Center Chief will collaborate with the U.S. Department of the Interior, the U.S. Department of Energy, and the AMWG/TWG: (1) to assure that the direction of the GCDAMP strategic plan is kept current and reflects the revision of priority goals, information needs, and desired future resource conditions; (2) to develop approaches for resolving GCDAMP budget limitations in the face of increasing science and management needs; (3) to facilitate the design of a partnership plan and program to transition major science treatments into management actions with appropriate responsibilities, authorities, and funding; and (4) to develop greater interaction between the Upper Colorado River Recovery Implementation Program and the Lower Colorado River Multi-species Conservation Plan to share science findings, methods, and management actions.

GCMRC Budget

A general assessment of the GCMRC's budget needs during the next 5 years, FY07–FY11, indicates that the planned science activities could be accomplished with moderate budget increases. To create and advance a comprehensive science program with moderate budget increases will require the effective management of priorities, the termination of selected programs, and the extension of proposed time frames for activities related to lower-priority goals and information needs. Additionally, the implementation of experimental research projects will require careful planning to avoid major disruptions to planned and ongoing activities.

To minimize the impacts of unpredictable events on the program over the next 5–10 years, the GCMRC will pursue selected budget management strategies:

- To develop and approve detailed project descriptions and budgets in the biennial work plan;
- To develop protocols for establishing a contingency fund sufficient to support anticipated future experimental projects;
- To conserve a percentage of overall funds for reallocating at the discretion of the Center Chief when savings or shortfalls occur in specific areas;
- To develop protocols for guiding external budget development by the GCMRC to respond to issues affecting the GCDAMP, but currently outside the GCDAMP budget process; and
- To seek additional congressional funding to support research to address (1) testing/operation of a temperature control device and other large capital projects and (2) external factors or issues outside the scope of the GCDAMP that impact GCDAMP goals.

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