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March 6, 2009

MEMORANDUM

To: Technical Work Group, Glen Canyon Dam Adaptive Management Program

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

Subject: Amendment to GCMRC's Strategic Science Plan and the Monitoring and Research Plan

In May 2008, the AMWG passed a motion that authorized the TWG to work with GCMRC to update the Monitoring and Research Plan (MRP) to reflect the new priorities and provisions of the 2007 Biological Opinion concerning the shortage guidelines and coordinated operations of Lakes Powell and Mead, the 2008 Biological Opinion for the Operation of Glen Canyon Dam, and the associated Environmental Assessment (EA); and to report recommended MRP changes to the AMWG for review and approval by its Fall/Winter 2008 meeting. While not referenced in the AMWG motion, I felt it was important to also update the Strategic Science Plan (SSP) which provides the foundation for the MRP.

A revised draft of the SSP and MRP was shared with the TWG in September 2008 and discussed at the October 2008 TWG meeting. TWG members were asked to provide comments on the revised SSP and MRP. With respect to the SSP, about 25 comments were received (attached). No changes were made to the SSP in response to these comments since, in my view, all the comments were all outside the scope of the intended revision. Proposed revisions to the SSP (attached) are highlighted in yellow. The September 2008 draft of the SSP proposed extending the timeframe of the SSP to 2012 to correspond to the timeframe of the experimental plan outlined in the EA. Given the broader issues that were raised by commenter's about the SSP, I decided to maintain the 2007-2011 timeframe for the SSP.

Over 350 comments were provided from 17 reviewers on the MRP. In reviewing the comments, it became clear that most of the comments were outside the scope of the planned revision; a comprehensive revision of the MRP would be required to address all the comments that were received. Such a major revision was outside the scope of the motion passed by the AMWG. Therefore, I made a decision to leave the current approved

MRP intact and prepare a stand alone amendment (attached) that identifies GCMRC science activities that will be carried out to address key provisions of the EA and biological opinions. Relevant reviewer comments were considered in the development of the attached amendment. Copies of the comments and our response to some of the comments are available upon request.

In keeping with the AMWG motion, I am seeking a recommendation from the TWG on the proposed SSP revisions and the MRP amendment. I would also welcome comments that would make the revision/amendment more acceptable to the TWG. I intend to present the revised SSP and MRP amendment to the AMWG for review and approval at their April 2009 meeting. A copy of the comment response form is provided for your use in providing written comments on the SSP or MRP revision.

Thanks for your consideration. I look forward to discussing this further at the upcoming TWG meeting

Attachment (4)
1. Comments on the September 2008 TWG Review draft of the Strategic Science Plan
2. Strategic Science Plan
3. Monitoring and Research Plan (MRP) Amendment
4. Comment Sheet

Attachment 1. Comments on the September 2008 TWG Review draft of the Strategic Science Plan

Document Title Strategic Science Plan for FY 2009-12
Document Date: October 2008

Comment Number	Page	Line	Reviewer Name	Affiliation	Reviewer Comments (Be specific	Identify Action Requested	Response Requested	GCMRC Response/Action Taken
	General		**Henderson**	**NPS/GLCA**	The revised draft SSP included additions only. Significant deletions occurred that affect overall priority and direction of the science program, i.e., TCD.	**Release a revised draft with both additions and deletions.**		
	1	**Preface**	**Henderson**	**NPS/GLCA**	Clarify that the SSP is responsive to NPS managers at GRCA/GLCA as well as the AMP.			**Outside scope of the revision**
	1	**Intro/ background**	**Henderson**	**NPS/GLCA**	Discussion in this section should include more than the AMP. As above, the SSP should recognize the resource priorities and ongoing RM/monitoring activities conducted by the NPS. Also, the NPS role in protecting and managing GRCA/GLCA resources should be mentioned. The SSP should describe how GCMRC research and monitoring will intersect with these NPS programs within the CRE.			**Outside scope of the revision**
	1	**6**	**Sam Spiller**	**FWS**	After "… identified by the Adaptive Management Work Group [add] and the stewardship responsibilities of DOI managing agencies for the Public."	**Requested addition that would replace existing wording.**	**Yes**	**Outside scope of the revision**
	1	**29-42**	**Sam Spiller**	**FWS**	**I would use the exact same wording as used for the MRP (or vice versa). Since I started reviewing the MRP first, I have made comments. My recommendation is to address my requested comment changes and then, once wording is addressed for**	**Requested addition that would replace existing wording.**	**Yes**	**Outside scope of the revision**

Comment Number	Page	Line	Reviewer Name	Affiliation	Reviewer Comments (Be specific	Identify Action Requested	Response Requested	GCMRC Response/Action Taken
					items 1-5 in the MRP, use that wording for items 1-5 in the SSP.			
	2	**8**	**Henderson**	**NPS/GLCA**	The term natural resources should be replaced with one that is more expansive and includes all the resources specified in the GCPA (natural, cultural, recreational, economic etc.)		**No**	**Outside scope of the revision**
	2	**Adaptive Management & Table 1**	**Henderson**	**NPS/GLCA**	This section should clearly specify how GCMRC interacts with NPS to implement the proposed science program. Ultimately, it is the needs of the NPS and other DOI agencies that must be met (with input and recommendations from the AMWG).			**Outside scope of the revision**
	2	**Adaptive Management**	**Henderson**	**NPS/GLCA**	By reading this section, the reader is left with the impression that the adaptive management program manages the resources in Grand Canyon National Park and Glen Canyon National Recreation Area. This section should specifically mention that the GCMRC science program provides data and analyses to support the formal five-year review of the GCD operating criteria and the annual plan of operations for GCD and report to congress.			**Outside scope of the revision**
	2	**Figure 1**	**Sam Spiller**	**FWS**	**Recommend adding Bureau of Reclamation, National Park Service, Bureau of Indian Affairs, and Fish and Wildlife Service within the portion of the Figure depicting our Secretary of the Interior due to the collective, magnitude of importance that the stewardship and associated management responsibilities of these DOI bureaus. Further, recommend one sentence descriptors that identify the responsibilities of these agencies in an additional paragraph that follows the 1st paragraph on page 1, to support the**	**Requested addition that would replace existing wording.**	**Yes**	**Outside scope of the revision**

Comment Number	Page	Line	Reviewer Name	Affiliation	Reviewer Comments (Be specific	Identify Action Requested	Response Requested	GCMRC Response/Action Taken
					stewardship responsibilities of the Secretary of the Interior and importance of the GCMRC work.			
	2	**5**	**Sam Spiller**	**FWS**	**Include reference to our Secretary of the Interior Adaptive Management guidance document in this first sentence.**	**Requested addition that would replace existing wording.**	**Yes**	**Outside scope of the revision**
	3	**19-20**	**Henderson**	**NPS/GLCA**	The GCDAMP must also be responsive to the dfcs specified by the NPS.			**Outside scope of the revision**
	5	**Integrated River Science**	**Henderson**	**NPS/GLCA**	The importance of economics should be discussed in terms of all resources (including hydropower). Economic cost/benefits are routinely used to justify resource decisions and should be used in the AMP program.			**Outside scope of the revision**
	5	**8**	**Henderson**	**NPS/GLCA**	Change 5 years to 4 years		**No**	**Outside scope of the revision**
	6	**Lead roles Of GCMRC**	**Henderson**	**NPS/GLCA**	A key role of GCMRC is to advise the DOI agencies charged with management of GRCA/GLCA resources.			**Outside scope of the revision**
	6	**Lead roles of GCDAMP**	**Henderson**	**NPS/GLCA**	1. The AMP does not provide "management direction." That is the responsibility of DOI agencies. The AMP reviews and makes recommendations on proposed management direction. 2. The GCDAMP does not "implement" management actions and treatment programs. The AMP recommends agencies like the NPS take actions and treatment programs.			**Outside scope of the revision**
	6	**14**	**Henderson**	**NPS/GLCA**	The 2006 Roles Ad Hoc group report was updated this year. Shouldn't the latest version be referenced?			**Outside scope of the revision**
	8		Davis	CREDA	The list of key strategic science questions under the question "What is the best flow regime?" show many projected dates that have already past even though the monitoring and research to answer the questions has not	Please provide information on the status of these projects or when these	Y	**Outside scope of the revision**

Comment Number	Page	Line	Reviewer Name	Affiliation	Reviewer Comments (Be specific	Identify Action Requested	Response Requested	GCMRC Response/Action Taken
					been completed. Of the 12 questions, 6 were projected to be done by now and another 4 were to be done by FY09. What is the status of efforts to incorporate monitoring and research into the GCMRC budget to answer these questions?	projects are scheduled to be conducted.		
	9	**AMWG priority 3**	**Henderson**	**NPS/GLCA**	Add a question about economic cost/benefit of the best flow regime.			**Outside scope of the revision**
	9	**AMWG priority 4**	**Henderson**	**NPS/GLCA**	Add a question about total economic costs/benefits of sediment loss			**Outside scope of the revision**
	9	**35**	**Henderson**	**NPS/GLCA**	Clarify this note. It appears that a reference is being made to the LTEP which has been suspended			**Outside scope of the revision**
	9	**Other critical research and monitoring needs**	**Henderson**	**NPS/GLCA**	The need for comprehensive economic value determinations should be stressed in this section. The program can no longer just evaluate the economic impacts to hydropower.			**Outside scope of the revision**
	Entirety of SSP		**Sam Spiller**	**FWS**	**I believe additional reference is needed throughout the document to acknowledge the stewardship roles of the DOI agencies as reasoning and/or justification for GCMRC monitoring and research work ; this should be supportive to further the importance of GCMRC's science work.**	**Requested addition that would replace existing wording.**	**Yes**	**Outside scope of the revision**

Attachment 2
TWG Review Draft—March 6, 2009

Developed in cooperation with the Glen Canyon Dam Adaptive Management Program

Strategic Science Plan to Support the Glen Canyon Dam Adaptive Management Program, Fiscal Years 2007-2011

Prepared by the USGS Grand Canyon Monitoring and Research Center

Final
March 22, 2007
Amended
April 2009

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

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia 2007

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Suggested citation:
U.S. Geological Survey, 2007, Monitoring and research plan in support of the Glen Canyon Dam Adaptive Management Program: Flagstaff, Ariz., U.S. Geological Survey, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, 149 p.

Preface

This "Strategic Science Plan to Support the Glen Canyon Dam Adaptive Management Program, Fiscal Years 2007-2011" is one element of an overall science-planning process used by the Grand Canyon Monitoring and Research Center (GCMRC) to provide independent, objective science support to the Glen Canyon Dam Adaptive Management Program. We designed the plan to be responsive to the goals and the priority information needs identified by the Adaptive Management Work Group The Adaptive Management Work Group is a Federal Advisory Committee that makes recommendations to the Secretary of the Interior on the operation of Glen Canyon Dam and other management actions intended to meet the U.S. Department of the Interior's obligations under the Grand Canyon Protection Act. The strategies presented here will be used to guide the development and implementation of monitoring and research activities for fiscal years (FY) 2007–11. The Plan was updated in April 2009 to reflect provisions of several NEPA documents and U.S. Fish and Wildlife Service biological opinions related to the operation of Glen Canyon Dam.

Copies of this plan are available at *http://www.gcmrc.gov/*.

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) to provide credible, objective scientific information to the Glen Canyon Dam Adaptive Management Program (GCDAMP) during the next 5 years. The study area of interest to the GCDAMP is the Colorado River corridor from Glen Canyon Dam to Lake Mead, an area known as the Colorado River ecosystem (CRE). For the study area, the GCMRC will develop scientific information regarding (1) the effects of the operation of Glen Canyon Dam and other factors on CRE resources, using an ecosystem approach, and (2) flow and nonflow measures to mitigate adverse effects on CRE resources caused by dam operations. This SSP will be carried out by the GCMRC in cooperation with participants of the GCDAMP.

The GCDAMP 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—the dynamic interplay of stakeholder collaboration, resources management, and scientific research—was envisioned as a new paradigm to address the complex environmental problems related to the operation of Glen Canyon Dam. The GCDAMP consists of five components (fig. 1):

- The Adaptive Management Work Group (AMWG) is a Federal Advisory Committee that facilitates the implementation of the GCDAMP. The AMWG is made up of 25 stakeholders and the Secretary of the Interior's Designee. The AMWG makes recommendations to the Secretary of the Interior on how dam

operations can be modified or other management actions taken 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 as a direct link between the AMWG and the Secretary of the Interior.
- The Technical Work Group (TWG) translates AMWG 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 USGS Grand Canyon Monitoring and Research Center provides credible, objective scientific information on the effects 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 GCMRC responsibilities).
- Independent review panels assesses proposals and research products to ensure scientific objectivity and credibility. The science advisors, a formal group of academic experts in fields germane to the GCDAMP, are an example of 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 commonly called "adaptive management." The approach assumes that managed natural resources will always change, that scientific understanding of ecosystems is constantly improving, and that natural resource managers need the best available information to make decisions. AEAM unites the strengths of different scientific disciplines to meet the information needs of resource managers. It encourages scientists and managers to work collaboratively to use scientific information in the management process.

AEAM consists of two parts—adaptive assessment and adaptive management. Assessment investigates how ecological systems work and evaluates management alternatives to achieve goals. Management involves learning by doing and testing, which may include monitoring system responses to natural changes (passive adaptive management) or deliberate manipulation of key processes (active adaptive management).

Adaptive management acknowledges that policies must satisfy social objectives, but policies also need to adapt to both changes in understanding and changes in managed systems. Managers using an AEAM approach learn how a natural system works and how their actions affect the system; this knowledge helps them to perform better in complex and uncertain environments. This SSP is based on an AEAM approach articulated in the draft GCDAMP strategic plan (2000), which includes the following activities:

1. Development of models on the effects of policies, activities, or practices being considered for implementation

2. Formulation of questions as testable hypotheses regarding the expected responses or linkages of the Colorado River ecosystem to dam operations and management actions
3. Execution of experiments to test hypotheses and answer questions
4. Implementation of management actions to reveal the accuracy or completeness of earlier predictions through monitoring and evaluation of results
5. Incorporation of new information produced through experimentation into management discussions and recommendations to the Secretary of the Interior

Science Planning Process

The GCDAMP science planning process aims to develop a credible, objective science program that is responsive to AMWG goals and priority needs. 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 five priority questions to help guide the GCDAMP science program:

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. 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. What is the best flow regime?
4. What is the impact of sediment loss and what should we do about it?
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 five priority questions as the primary, but not exclusive, basis for designing the science program to be implemented during the next 5 years. Other sources of information that will be considered include the following:

- 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
- National Historic Preservation Act requirements
- NEPA documents and U.S. Fish and Wildlife Service biological opinion requirements related to the operation of Glen Canyon Dam. For example, the Environmental Assessment: Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012 dated February 29, 2008, the Final Biological Opinion for the Bureau of Reclamation's Operation of Glen Canyon Dam, February 27, 2008, and the Final Biological Opinion for

the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, December 12, 2008 will be used to provide direction for several research, monitoring, and experimental activities that will be carried out in FY2008-20212 including a March 2008 High Flow Experiment and a 5-year Nearshore Ecology-Steady Flow Experiment.

The science program will also incorporate the findings of an environmental impact statement (EIS) on a long-term experimental plan (LTEP) for the operation of Glen Canyon Dam and associated management activities. The EIS process was begun by the Bureau of Reclamation in late 2006; however, the process was temporarily suspended in 2008 to allow the agency to focus on Endangered Species Act and National Environmental Policy Act compliance required for a 5-year plan of experimental flows from Glen Canyon Dam. The experimental flow plan includes the high-flow release conducted in early March 2008. The eventual results of the EIS will be incorporated into the SSP and other GCMRC planning documents noted below when a Record of Decision is issued.

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

Science Planning Documents

The GCMRC will design and implement the GCDAMP science program in cooperation with GCDAMP stakeholders through collaboration on four stepdown planning documents:

1. The GCDAMP strategic plan (AMPSP) is a long-term plan drafted in August 2001 by GCDAMP and GCMRC participants that identifies the AMWG's vision, mission, principles, goals, management objectives, information needs, and management actions (Glen Canyon Dam Adaptive Management Program, 2001).
2. The GCMRC SSP (this document) identifies general strategies for the next 5 years to provide science information responsive to the goals, management objectives, and priority questions as described in the AMPSP and other planning direction approved by the AMWG.
3. The GCMRC monitoring and research plan (MRP) specifies (1) core monitoring activities, (2) research and development activities, and (3) long-term experimental activities consistent with the strategies and priorities established in this SSP to be conducted over the next 5 years to address some of the strategic science questions associated with AMWG priority questions. (Other strategic science questions will be addressed through the LTEP EIS.)
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 years 2007 and 2008. The first BWP is currently in progress.

Figure 2 depicts the flow of information in the stepdown science planning and implementation process.

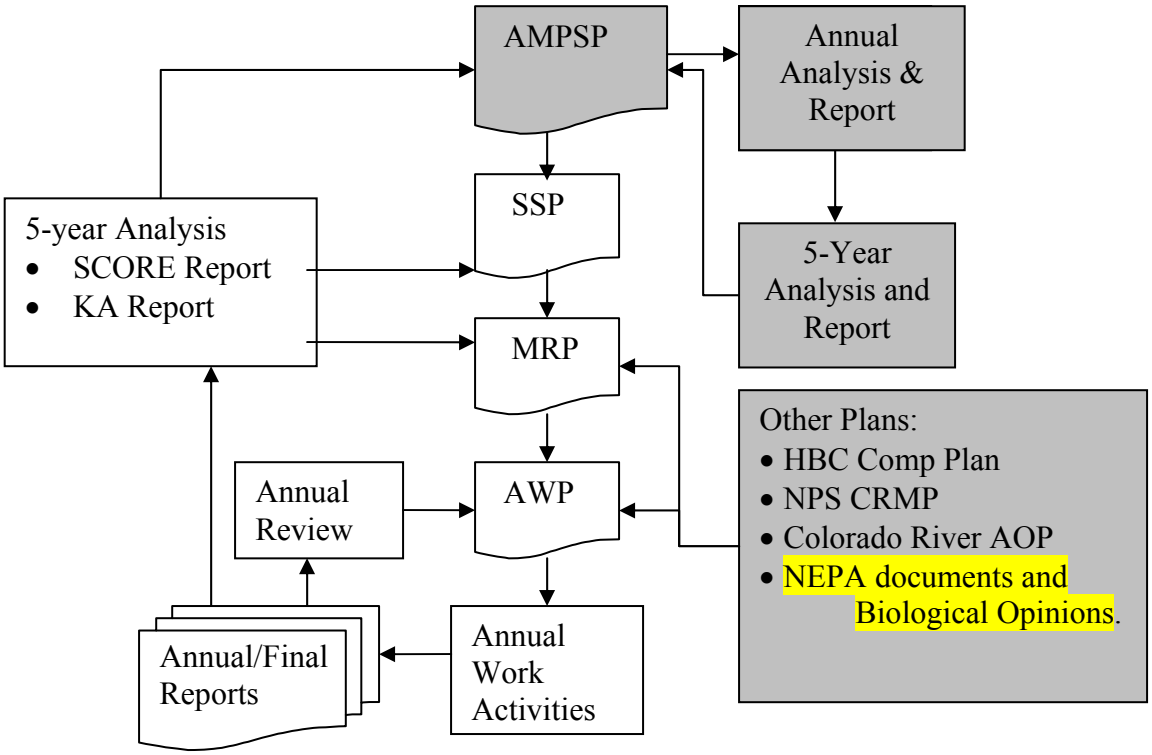

Figure 2. Collaborative science planning and implementation process. The Glen Canyon Dam Adaptive Management Program and the U.S. Department of the Interior have lead responsibility for the shaded boxes. The Grand Canyon Monitoring and Research Center haslead responsibility for the boxes that are not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

The GCMRC will report annually on completed projects presented in the biennial work plan and evaluate whether scientific research has contributed to fulfilling GCDAMP goals and management objectives. At 5-year intervals, the GCMRC will consolidate new scientific knowledge in updated versions of "The State of the Colorado River Ecosystem in Grand Canyon" (SCORE) report (Gloss and others, 2005), knowledge assessment report (Melis and others, 2006), and elsewhere, as appropriate. Priority information needs and science questions will be evaluated by scientists and managers to determine whether 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 treatments and actions. Completing concurrent reviews will help ensure the science program is properly aligned with current management objectives and priorities.

Science Strategies

This SSP is based on the adaptive management paradigm discussed above wherein new science information is continually cycled into application by managers, and outcomes are monitored by scientists and managers for effectiveness. This 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:

- Performing interdisciplinary, integrated river science
- Building bridges between science and management
- Formulating strategic science questions to address the AMWG's priority goals and questions
- Addressing critical research and monitoring needs outside the scope of the GCDAMP

Interdisciplinary, Integrated River Science

The GCMRC will increase its emphasis on an interdisciplinary, integrated science approach over the next 5 years. This approach supports AMWG goals to manage competing resource values to benefit both human beings and the natural ecosystems that are important to them. 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 seek to understand 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 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 (see Walters and others, 2000). The Grand Canyon Model that resulted proved to be useful at identifying knowledge gaps and predicting the response of some ecosystem components to policy change. However, a lack of data for some resource responses limited the effectiveness of the model to produce predictions 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 utility 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 will 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 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 with distinct but complementary roles. These individual roles and responsibilities are outlined in table 3. A

more complete discussion of roles and responsibilities of various GCDAMP entities and the GCMRC is presented in the report of the Roles Ad Hoc Group of the GCDAMP (2006).

The success of the GCDAMP is dependent not only on the GCMRC's ability to produce scientific information that is relevant to management needs but also upon the effective and timely use of that information by managers in the decisionmaking 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 timeframes. 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 in understanding the interrelationships, data uncertainty, and relative influence of scientific knowledge on resource management decisions.

The GCMRC proposes a collaborative strategy among scientists and GCDAMP participants to assess how to better integrate scientific information into the GCDAMP process. The assessment will address (1) the feasibility of using decision-support tools to integrate scientific information into science planning and AMP recommendation processes, including resource tradeoff assessments, and (2) strategies to address the value-based conflicts of diverse interests in the GCDAMP. Pilot approaches will be tested during the FY2007–11 program period.

Addressing Priority Goals and Questions

In general, the GCMRC science program will monitor the status and trends of CRE resources and evaluate treatments or management actions (e.g., changes in dam operation, nonnative fish control, beach/habitat-building flows, etc.) to restore or protect downstream resources. The science program will address AMWG priority questions and key strategic science questions, presented in the following section, that were identified in the knowledge assessment report (Melis and others, 2006). Providing answers to these key questions will provide the information needed by managers to improve management of priority CRE resources and reduce the uncertainties associated with various flow and nonflow treatments or management actions being considered by the GCDAMP.

The strategic science questions will be addressed through the following general categories of activities:

1. Core-monitoring activities are scientifically validated protocols or methods to assess the condition and trend of priority GCDAMP resources (humpback chub, sediment, food base, etc.).
2. Research and development activities include research projects aimed at (1) addressing hypotheses or information needs related to a priority GCDAMP resources or (1) developing and testing new technologies or monitoring procedures.
3. Long-term experimental activities include a suite of flow and nonflow treatments, monitoring and research, and management actions (1) to improve the condition of target resources (humpback chub, cultural sites, sediment, etc.) and (2) to

understand the relationship between treatments and management actions and target resources.

Activities will be defined in the MRP and BWP and will be based on the knowledge assessment report, core-monitoring information needs, research information needs, NEPA and ESA compliance requirements, and other relevant information. The MRP and BWP will identify each activity's objectives, methods, outcomes, and costs by fiscal year. An interdisciplinary, integrated science approach as described above will be used, where appropriate.

The GCMRC will coordinate its research activities with other institutions conducting research in the CRE to ensure a cost-effective ecosystem approach. All GCMRC work plans and reports will be subjected to independent peer review consistent with the USGS Fundamental Science Practices, a set of guidelines and policies to ensure the world-class quality of USGS science products, and periodic comprehensive reviews of planned research or scientific work by panels of independent scientists.

AMWG Priority Questions and Related Strategic Science Questions

In 2004, the AMWG identified five priority questions related to the 12 goals that provide general guidance for planning, monitoring, and research efforts (table 2). The strategic science questions that appear below each of the five AMWG priorities were identified through two knowledge assessment workshops and presented in a summary report (Melis and others, 2006). The bracketed dates associated with each strategic science question indicate the time anticipated to complete monitoring and research activities required to address the question.

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?

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? [FY2006–11]
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? [FY2006–11]
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? [FY2007–11]
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. [FY2007–11]

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? [FY2006–09]
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? [FY2006–09]
7. Which tributary and mainstem habitats are most important to native fishes and how can these habitats best be made usable and maintained? [FY2008–09]
8. How can native and nonnative fishes best be monitored while minimizing impacts from capture and handling or sampling? [FY2007–11]

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?

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? [FY2007–11]
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? [FY2004–11]
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? [FY2009–11]
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? [FY2006–11]
5. What are the TCPs in the CRE, and where are they located? [FY2006–11]
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? [FY2006–08]
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? [FY2006–11]

AMWG Priority 3: What is the best flow regime?

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? [FY2008–11]
2. To what extent could predation impacts by nonnative fish be mitigated by higher turbidity or dam-controlled high-flow releases? [FY2007–08]
3. What are the hydropower replacement costs of the modified low fluctuating flow (annually, since 1996)? [FY2007–08]
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)? [FY2006–07]
5. How is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations? [FY2006–09]
6. What Glen Canyon Dam operations (ramping rates, daily flow range, etc.) maximize trout fishing opportunities and catchability? [FY2007–08]
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? [FY2007–08]
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? [FY2007–09]
9. How do varying flows positively or negatively affect campsite attributes that are important to visitor experience? [FY2009–11]
10. How can safety and navigability be reliably measured relative to flows? [FY2007–08]
11. How do varying flows positively or negatively affect visitor safety, health, and navigability of the rapids? [FY2007–09]
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? [FY2007–09]

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

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 timescales? [FY2008–11]
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? [FY2007–11]

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?

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? [FY2006–08]
2. How is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations? [FY2006–08]
3. To what extent do temperature and fluctuations in flow limit spawning and incubation success for native fish? [FY2003–08]
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? [FY2003–08]
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? [FY2003–08]
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? [FY2007–11]
7. How do warmer releases affect viability and productivity of native/nonnative vegetation? [FY2007–11]

Other Critical Research and Monitoring Needs

This section focuses on the critical need to address issues outside the CRE that impact the GCDAMP 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 dependent on the quality of water leaving the Little Colorado River. However, Little Colorado River water quality is evaluated on an infrequent basis and then only in the first few miles of its confluence with the Colorado River. No science activity currently exists to identify changes in Little Colorado River water quality and quantity resulting from upstream diversions, pollution, or catastrophic hazardous material spills.

The primary determinant of water quality in the CRE is the quality of the water released from Lake Powell. As a result, the water quality and dynamics of Lake Powell have major implications for the design of a device to regulate the temperature and other 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, extensively analyzed, or modeled. 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 for the proposed temperature control device.

Clearly, 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 to (1) work closely with the AMWG and the Department of the Interior to develop an endangered fish recovery program for the lower basin (Grand Canyon), (2) evaluate and report on the key external issues identified above that could affect attainment of GCDAMP goals, and (3) work with GCDAMP participants and others to secure funding for research on the issues that pose the highest risk or opportunity.

Administration and Budget

Staffing

The GCMRC's goal is to deliver in the next 5 years a comprehensive ecosystem science program that 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 need for a more comprehensive ecosystem science program in a flat budget environment. Improving science administration will require significant accomplishment 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 scientists to analyze and synthesize data and publish findings. GCMRC personnel will implement 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:

Chief

The Chief establishes GCMRC's science policies and strategic direction and provides budget accountability. The Chief ensures 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 ensure that quality science is provided in a timely manner on priority issues identified by the GCDAMP leadership.

Deputy Chief

The Deputy Chief supervises the science program, ensuring that integrated ecosystem procedures are used in science design and analysis. This position also has responsibility for monitoring peer-review processes using accepted procedures, tracking science project performance, and reporting program outcomes to ensure timely responses to GCDAMP information needs.

Program Managers

Program Managers are responsible for the timely execution of GCMRC science activities within their program area and interaction with other program areas to develop integrated ecosystem approaches to science products. Program Managers are therefore responsible for ensuring the quality of products produced by GCMRC staff, contractors and cooperators; overseeing contracts, agreements, and budgets for 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 of 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 conducted several experiments to determine if high-flow releases from Glen Canyon Dam have the ability to conserve sediment resources for building beaches 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 Program provides GIS, data quality control, data management, and library services to all program areas. In addition, this program oversees 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 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 culturally significant sites and artifacts and recreation activities based in Grand Canyon. Currently, the program is working on the development of comprehensive monitoring programs 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 to various programs and activities.

The GCMRC will rely on the USGS Southwest Biological Science Center, the parent organization of the GCMRC within the USGS, for administrative, budget, and contracting services; information technology; and policy support. The GCMRC will also work with the Southwest Biological Science Center 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 Chief will collaborate with the Department of the Interior, U.S. Department of Energy, and the AMWG and TWG to (1) ensure 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) develop approaches for resolving GCDAMP budget limitations in the face of increasing science and management needs; (3) 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) develop greater interaction among the Upper Colorado River Recovery Implementation Program and the Lower Colorado River Multi-Species Conservation Plan to share science findings, methods, and management actions.

Budget

A general assessment of the GCMRC's budget needs during the next 5 years, FY2007–11, indicates that the planned science activities could be accomplished with moderate increases in current budget allocations. To 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 timeframes 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 obviate the impacts of unpredictable events to the program over the next 5–10 years, the GCMRC will pursue the following selected budget management strategies:

- Develop and approve detailed project descriptions and budgets in the biennial work plan
- Develop protocols for establishing a contingency fund sufficient to support anticipated future experimental projects
- Conserve a percentage of overall funds for reallocating at the discretion of the Chief when savings or shortfalls occur in specific areas
- Develop protocols for guiding external budget development by the GCMRC to respond to issues affecting the GCDAMP, but currently outside the GCDAMP budget process
- Seek additional congressional funding to support research to address (1) testing and possible 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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DRAFT
Amendment
Monitoring and Research Plan to Support the Glen Canyon Dam Adaptive Management Program, Fiscal Years 2007–11
August 2007

March 6, 2009

The Monitoring and Research Plan to Support the Glen Canyon Dam Adaptive Management Program, Fiscal Years 2007–11, August 2007 (hereafter referred to as the MRP), was approved by the Secretary of the Interior on the condition that it would be updated to reflect the provisions of the Long Term Experimental Plan Environmental Impact Statement (LTEP EIS) for Glen Canyon Dam once that EIS was finalized. In lieu of the LTEP EIS, the Bureau of Reclamation (Reclamation) completed a Final Environmental Assessment: Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012 on February 29, 2008, (hereafter referred to as the EA). The purpose of this amendment is to address provisions of the EA and conservation measures from two U.S. Fish and Wildlife Service (FWS) Biological Opinions including:

- The Final Biological Opinion for the Bureau of Reclamation's Operation of Glen Canyon Dam, February 27, 2008
- The Final Biological Opinion for the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, December 12, 2008

Grand Canyon Monitoring and Research Center (GCMRC) science activities that will be conducted in support of the EA and the two Biological Opinions noted above are described below. A summary of those activities is provided in Table 1. More detailed description of these activities will be provided in the Annual/Biennial Work Plans.

Note: Descriptions of the elements of the EA and the Biological Opinion Conservation Measures below were derived directly from documents prepared by the Bureau of Reclamation and U.S. Fish and Wildlife Service.

Final Environmental Assessment: Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012, February 29 2008.
http://www.usbr.gov/uc/envdocs/ea/gc/2008hfe/GCDexprelEA.pdf. and related Findings Of No Significant Impact. http://www.usbr.gov/uc/envdocs/ea/gc/2008hfe/FONSI.pdf. The proposal consists of two types of experimental flows to be implemented beginning in 2008 and concluding in 2012: 1) an experimental high flow test of approximately 41,500 cfs for a maximum duration of 60 hours beginning March 4, 2008, and 2) steady flows in September and October of each year, 2008 through 2012. The overall concept of the experiment is to determine the effectiveness of sandbar building and backwater formation using a high flow test during highly enriched sediment conditions, and the subsequent impact on humpback chub in those backwaters during fluctuating flows in the spring and summer and steady flows in the fall. The timing of fall steady flows follows young-of-year emergence of humpback chub from the Little Colorado River into the mainstem. Intense monitoring and research conducted throughout this period will identify resultant effects on these geomorphic features and aquatic species. This proposed experiment neither mandates nor precludes future experimentation. Rather, this

proposed experiment was developed consistent with the principles of adaptive management to require full scientific and public analysis of the effects of the experiment and integration of such results into future decision making.

GCMRC Science Activities:

- ***March 2008 High Flow –*** *GCMRC will develop and implement a comprehensive science plan to evaluate the affects of the March 2008 high flow. The High flow Experiment (HFE) will address a variety of strategic science questions (Table 2) related to the effects of the high flow on sand bars and related backwater habitats, rainbow trout, camping beaches, aquatic food base, riparian vegetation, archaeological sites, and Lake Powell water quality. Table 3 summarizes the studies associated with the March 2008 HFE.*

  GCMRC will report the results of the March 2008 HFE in FY2009 and 2010, and synthesize of the results of the 1996, 2004, and 2008 high flow in FY2010. As part of the reporting process, GCMRC will work with the Adaptive Management Work Group (AMWG) and Department of Interior (DOI) agencies to provide recommendations for future high flows and related research and monitoring.

- ***Modified Low Fluctuating Flow (MLFF) operations with Steady Flows in September and October (2008-2012)****. GCMRC is developing and implementing a science plan to investigate the nearshore ecology of humpback chub and other fishes along with the impacts to aquatic biota, including fishes, from the experimental fall steady flows. This plan is intended to investigate what impacts steady and MLFF flows have on these resources, including growth, survival, and recruitment of fishes, habitat use, and primary productivity. The nearshore ecology study plan will be expanded to specify recommended late summer-fall flow regimes that should be provided to maximize learning related to the impacts steady and MLFF flows on native and nonnative fishes. The scope of the scope of the studies will be determined in coordination with Reclamation, FWS, National Park Service (NPS), and the Technical Work Group (TWG). The near shore ecology-fall steady flow science plan will be completed by July 2009.*

Conservation measures from the Final Biological Opinion for the Bureau of Reclamation's Operation of Glen Canyon Dam, February 27, 2008
http://www.fws.gov/southwest/es/arizona/Documents/Biol_Opin/930167_R1_GCD_BO.pdf

Humpback Chub Consultation Trigger – Pursuant to 50 CFR § 402.16 (c), reinitiation of formal consultation is required and shall be requested by the Federal agency or by the FWS, where discretionary Federal involvement or control over the action has been retained or is authorized by law and if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered. Reclamation and FWS agree to specifically define this reinitiation trigger relative to humpback chub, in part, as being exceeded if the population of adult humpback chub (≥200 mm [7.87 in] TL) in Grand Canyon declines significantly, or, if in any single year, based on the age-structured mark recapture model (ASMR; Coggins, 2007), the population drops below 3,500 adult fish within the 95 percent confidence interval. FWS and Reclamation have agreed on this trigger based on the

current estimated population size and past population trend, genetic considerations, and the capabilities of the ASMR model to estimate population size. This number was derived as a conservative approach to preventing the population from declining to the minimum viable population size for humpback chub, estimated to be 2,100 adult fish (U.S. Fish and Wildlife Service, 2002), with consideration for a buffer and acknowledging the variance inherent in the ASMR resulting from age estimation based on recent results from this model (Coggins, 2007). This trigger provides additional protection against possible adverse affects to humpback chub from the proposed action. If the population of humpback chub declines to this level, Reclamation and FWS will consider appropriate actions through reinitiated section 7 consultation, for example, extending the period of steady releases to include July and August. Conversely, if the population of humpback chub expands significantly, FWS and Reclamation will consider the potential for reinitiation of consultation to determine if steady flows continue to be necessary.

GCMRC Science Activities:

In cooperation with FWS and the Arizona Game and Fish Department (AZGFD), GCMRC will monitor humpback chub populations in the Little Colorado River. The humpback chub monitoring effort will be subjected to external peer review in a protocol evaluation panel in May 2009. In addition, GCMRC will conduct an annual assessment of the population of adult humpback chub (≥200 mm [TL) using the age-structured mark recapture model (ASMR; Coggins, 2007). This information will be provided to the Bureau of Reclamation and the U.S. Fish and Wildlife Service for use in evaluating the potential for reinitiation of Endangered Species Act consultation to determine if the September-October steady flows should be continued, discontinued, or expanded.

Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon – Reclamation has been a primary contributor to the development of the Adaptive Management Program's (AMP) Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon. Reclamation will continue to work with AMP cooperators to develop a comprehensive approach to management of humpback chub. Reclamation has committed to specific conservation measures in this biological opinion, but will also consider funding and implementing other actions not identified here to implement the plan.

***GCMRC Science Activities**:*

GCMRC senior biology program staff will participate in the review of the humpback chub comprehensive plan. Some of the projects identified within the plan can be wholly or partially implemented by GCMRC under the auspices of the AMP work plan.

Humpback Chub Translocation – In coordination with other DOI AMP participants and through the AMP, Reclamation will assist NPS and the AMP in funding and implementation of translocation of humpback chub into tributaries of the Colorado River in Marble and Grand Canyons. Nonnative control in these tributaries will be an essential precursor to translocation, so Reclamation will help fund control of both cold and warm-water nonnative fish in tributaries, as well as efforts to translocate humpback chub into these tributaries. Havasu, Shinumo, and Bright Angel Creeks will initially be targeted for translocation, although other tributaries may be considered. Reclamation will work with FWS, NPS, and other cooperators to develop translocation plans for each of these streams, utilizing existing information available such as

SWCA and Grand Canyon Wildlands (2007) and Valdez et al. (2000). These plans will consider and utilize genetic assessments (Douglas and Douglas, 2007; Keeler-Foster, in prep), identify legal requirements and jurisdictional issues, methods, and assess needs for nonnative control, monitoring and other logistics, as well as an implementation schedule, funding sources, and permitting. Reclamation and the AMP will also fund and implement translocation of up to 500 young humpback chub from the lower Little Colorado River to above Chute Falls in 2008 if FWS determines that a translocation is warranted. Reclamation and the AMP will continue to monitor humpback chub in the reach of the Little Colorado River above Chute Falls for the 5-year period of the proposed action, and will undertake additional translocations above Chute Falls as deemed necessary by FWS.

GCMRC Science Activities:

In cooperation with the FWS, GCMRC currently plans to conduct annual monitoring of humpback chub in the reach of the Little Colorado River above Chute Falls, and undertake periodic humpback chub translocations above Chute Falls as deemed necessary by the FWS. This work will be subjected to external peer review in a protocol evaluation panel in May 2009. In addition, NPS and Reclamation are expected to translocate humpback chub from the Little Colorado River to Shinumo Creek in 2009 and potentially Havasu and Bright Angel Creeks in future years. Separate funding for translocation into these additional tributaries is being sought. GCMRC may be involved, especially in monitoring humpback chub that leave tributaries and enter the mainstem. NPS, Reclamation, and other tributary translocation cooperators are reviewing the need for nonnative control in advance of translocations (Shinumo Creek in 2009) and will implement such actions if determined to be needed by the group.

Nonnative Fish Control – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand Canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

GCMRC Science Activities:

GCMRC will prepare a nonnative fish control plan that addresses both cold and warm-water species to guide research and experimental efforts for control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand Canyons and in their tributaries. The primary research need in tributaries is to further the understanding of nonnative fish distributions; other agencies, including NPS, Reclamation, and FWS, have been pursuing nonnative control efforts in tributaries, especially Shinumo and Bright Angel Creeks. Part 1 of the nonnative control plan, detailing current information, available methods, and annual planning, will be completed in FY2009 and part 2, including a threats

assessment, is scheduled for delivery in September 2010. As noted in the quote from the Biological Opinion above, cool water releases from Glen Canyon Dam are predicted between 2008 and 2012, suggesting that control of nonnative trout species in the Little Colorado River reach of the mainstem will be the highest priority conservation measure, although all nonnatives encountered will be removed during the control effort. The preliminary goal will be to maintain rainbow trout numbers at 10 percent of the 2003 rainbow trout population estimate for the reach of the Colorado River downstream of the confluence with the Little Colorado River. Control methods for rainbow and brown trout in the mainstem were previously developed during an experimental period conducted by GCMRC and cooperators in 2003-2006. To facilitate this conservation measure, GCMRC will conduct mainstem nonnative control, together with cooperators in 2009 and proposes to transfer funding responsibility and lead for mainstem cold water nonnative control efforts to an appropriate management agency in FY2010 and later years.

As noted above, NPS, Reclamation, and other tributary translocation cooperators are reviewing the need for nonnative control efforts in advance of translocations. If such efforts are needed, these groups will pursue control and associated monitoring in tributaries.

As additional research and experimental questions related to nonnative control are identified GCMRC will develop work plans and budgets to address these questions and associated information needs. For example, GCMRC has been cooperating with AZGFD to improve catch methods for channel catfish FY2007-2009.

Humpback Chub Nearshore Ecology Study – In coordination with other DOI AMP participants and through the AMP, Reclamation will implement a nearshore ecology study that will relate river flow variables to ecological attributes of nearshore habitats (velocity, depth, temperature, productivity, etc.) and the relative importance of such habitat conditions to important life stages of native and nonnative fishes. This study will incorporate planned science activities for evaluating the high flow test on nearshore habitats as well as the 5-year period of steady flow releases in September and October. A research plan will be developed with FWS via the AMP for this study by August 1, 2008, and a 5-year review report will be completed by 2013. The plan will include monitoring of sufficient intensity to ensure significant relationships can be established, as acceptable to the FWS. This conservation measure is consistent with the Sediment Research conservation measure in the Shortage Guidelines biological opinion (see below). This study will help clarify the relationship between flows and mainstem habitat characteristics and availability for young-of-year and juvenile humpback chub, other native fish, and competitive or predaceous nonnative fish, and support continued management to sustain mainstem aggregations. The feasibility and effectiveness of marking small humpback chub (<150 and <100 mm TL [5.91 and 3.93 in]) will also be evaluated as part of the study, and if effective, marking young fish will be utilized in the study. Marking young humpback chub, if feasible and effective, could greatly aid in developing information on the early life history, growth, and survival of young humpback chub.

GCMRC Science Activities:

GCMRC will conduct a nearshore ecology study in FY2008-FY 2012 to relate varying river flows to ecological attributes of nearshore habitats to better understand the relative importance of such habitats to juvenile native and nonnative fishes. The nearshore ecology project will investigate the impacts of different flow regimes (MLFF, fall steady flows) on the growth and survival of juvenile humpback chub. Ecological characteristics include physical and biological parameters such as temperature, turbidity, primary productivity, and occupancy by other fish species. Together with an external cooperator identified through a competitive process, GCMRC will also investigate what habitats are occupied by juvenile humpback chub and how different habitats may affect growth, survival, and recruitment into the adult population.

Monthly Flow Transition Study – Transitions between monthly flow volumes can often result in drastic changes to nearshore habitats. For example, past transitions from August to September in some years have consisted of a transition from a lower limit of 10,000 cfs in August to an upper limit of 10,000 cfs in September. Such a transition results in a river stage level that is below the varial zone of the previous month's flow, and may be detrimental to fishes and food base for fish. Reclamation has committed to adjusting daily flows between months to attempt to attenuate these transitions such that they are more gradual, and to studying the biological effects of these transitions, in particular to humpback chub. If possible, Reclamation will work to adjust September and October monthly flow volumes to achieve improved conditions for young-of-year, juvenile, and adult humpback chub, as acceptable to the FWS.

GCMRC Science Activities:

Because the nearshore ecology project will be conducted at the time of year when flows transition from MLFF to the experimental steady flows, this study will also permit some evaluation of how juvenile humpback chub and other fishes respond to the flow transition. GCMRC intends to augment the work conducted by the nearshore ecology project with additional food base investigations, particularly evaluation of how various flows and the changes in flows may impact the content and/or volume of drifting organic material.

Humpback Chub Refuge – Once appropriate planning documents are in place, and refuge populations of humpback chub are created (as a conservation measure of the Shortage Guidelines biological opinion), Reclamation will assist FWS in maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing funding to assist in annual maintenance. In case of a catastrophic loss of the Grand Canyon population of humpback chub, a humpback chub refuge will provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species. This action would also be an important step toward attaining recovery.

GCMRC Science Activities:

GCMRC senior biology program staff will participate in the review of refuge plans.

Little Colorado River Watershed Planning – Reclamation will continue its efforts to help other stakeholders in the Little Colorado River watershed develop watershed planning efforts, with consideration for watershed level effects to the humpback chub in Grand Canyon.

GCMRC Science Activities:

GCMRC will provide any data that have been collected in the AMP program regarding biological and water resources in the Little Colorado River. GCMRC will advise the Little Colorado River watershed planning effort on the potential impact that watershed development activities may have on humpback chub in the Little Colorado River. GCMRC and other fish cooperators, primarily FWS and AZGFD, have identified the risk from nonnatives in the LCR to humpback chub as a concern. The fish cooperators propose to document nonnative source populations in future years as funding permits.

Kanab Ambersnail Habitat Protection – Reclamation will, through the AMP, temporarily remove and safeguard all Kanab ambersnails found in the zone that would be inundated during the high flow test, as well as approximately 15 percent (17 m2 [180 ft2]) of the Kanab ambersnail habitat that would be flooded by the experimental high flow test. The Kanab ambersnails would be released above the inundation zone, and habitat would be held locally above the level of inundation until the high flow test has ended (approximately 60 hours). Habitat will be replaced in a manner that will facilitate regrowth of vegetation. Subsequent monitoring of this conservation measure will be coordinated with GCMRC.

GCMRC Science Activities:

Temporary removal of Kanab ambersnail habitat found in the zone that would be inundated during the high flow test is an element of the HFE science plan (Table 3). This conservation actions was conducted in March 2008. Surveys in September 2008 indicated that vegetation (Kanab ambersnail habitat) moved in anticipation of the HFE had re-established following the HFE.

Conservation measures from the Final Biological Opinion for the Bureau of Reclamation's Proposed Adoption of Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, December 12, 2008
http://www.fws.gov/southwest/es/arizona/Documents/Biol_Opin/06224_final_shortage.pdf

Nonnative Fish Control – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue efforts to control both cold- and warm-water nonnative fish species in the mainstem of Marble and Grand Canyons, including determining and implementing levels of nonnative fish control as necessary. Control of these species using mechanical removal and other methods will help to reduce this threat.

GCMRC Science Activities:

See Nonnative Fish Control, above

Humpback Chub Refuge – Reclamation will assist FWS in development and funding of a broodstock management plan and creation and maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing expedited advancement of $200,000 in funding to the FWS during CY2008; this amount shall be funded from, and within, the amount identified in the MSCP BO (U.S. Fish and Wildlife Service, 2005; page 26). Creation of a humpback chub refuge will reduce or eliminate the potential for a

catastrophic loss of the Grand Canyon population of humpback chub by providing a permanent source of genetically representative stock for repatriating the species.

GCMRC Science Activities:

See Humpback Chub Refuge, above

Genetic Biocontrol Symposium – Reclamation will transfer up to $20,000 in FY2008 to FWS to help fund an international symposium on the use and development of genetic biocontrol of nonnative invasive aquatic species which is tentatively scheduled for October 2009. Although only in its infancy, genetic biocontrol of nonnative species is attracting worldwide attention as a potential method of controlling aquatic invasive species. Helping fund an effort to bring researchers together will create further awareness of this potential method of control and help mobilize efforts for its research and development.

GCMRC Science Activities:

None

Sediment Research – In coordination with other DOI AMP participants and through the AMP, Reclamation will monitor the effect of sediment transport on humpback chub habitat and will work with the GCMRC to develop and implement a scientific monitoring plan acceptable to FWS. Although the effects of dam operation-related changes in sediment transport on humpback chub habitat are not well understood, humpback chub are known to utilize backwaters and other habitat features that require fine sediment for their formation and maintenance. Additional research will help clarify this relationship.

GCMRC Science Activities:

The March 2008 High Flow Experiment Science Plan (see above), the nearshore ecology study (see above), and ongoing sediment and fish monitoring will all contribute to a better understanding of the effect of sand enriched high flows combined with normal MLFF dam operations on suspended-sediment transport, geomorphic processes tied to sandbars/ backwater formation and fate of sand derived, nearshore humpback chub habitat.

Parasite Monitoring – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue to support research on the effects of Asian tapeworm (*Bothriocephalus acheilognathi*) on humpback chub and potential methods to control this parasite. Continuing research will help better understand the degree of this threat and the potential for management actions to minimize it.

GCMRC Science Activities:

An intensive study of this issue (Linder and others, 2008) funded by the AMP concluded that parasite loads in humpback chub were variable, i.e., high in some locations, low in others. They also concluded that there was no statistically significant correlation between parasite load and fish size, suggesting that parasites had limited impact on fish growth. The report recommends a parasite monitoring frequency of once every 5-6 years. In keeping with this recommendation GCMRC will propose another survey to assess parasite loads in Grand Canyon fishes be conducted in 2012.

Kanab Ambersnail Monitoring and Research – Through the AMP, Reclamation will continue to monitor Kanab ambersnail and its habitat in Grand Canyon and the effect of dam releases on the species, and Reclamation will also continue to assist FWS in funding morphometric and genetic research to better determine the taxonomic status of the subspecies.

GCMRC Science Activities:

GCMRC has supported genetic research of this species by conducting the external peer review of the morphometric and molecular taxonomic study. This study is in draft form and is expected to be complete in 2009.

Southwestern Willow Flycatcher Monitoring and Research – Through the AMP, Reclamation will continue to monitor southwestern willow flycatcher and its habitat and the effect of dam releases on the species throughout Grand Canyon and report findings to FWS, and will work with the NPS and other AMP participants to identify actions to conserve the flycatcher.

GCMRC Science Activities:

The support that GCMRC provides for the study of birds in Grand Canyon includes the ongoing studies of the riparian habitat. GCMRC produced a vegetation community map of the entire river corridor, using 2002 data, in a report published in 2008 (Ralston and others, 2008). GCMRC initiated development of a Terrestrial Ecosystem Monitoring program that was temporarily put on hold but which has been proposed for re-initiation in 2010. The initial focus of renewed terrestrial monitoring, to accompany continuing vegetation monitoring, is monitoring of the arthropods of the riparian corridor because they are an important prey base for many terrestrial vertebrates, including amphibians, reptiles, and birds. Ongoing mapping and change detection for riparian vegetation is supported by overflight data from previous years and by the planned 2009 overflight.

Table 1. Summarized elements of the EA and Biological Opinion Conservation Measures within GCMRC's Monitoring and Research Plan throughout the Colorado River ecosystem (CRE) to Support the GCDAMP, Fiscal Years 2007–11

EA Elements and Biological Opinion Conservation Measures	Monitoring	Research and Development	Experimental Research & Planning
EA Elements			
▪ High Flow Experiment (highly sand enriched conditions)	Suspended-sediment transport and sand storage changes tied to habitats, plus quality of water in Lake Powell and CRE	Integrated flow, sediment and temperature model development	Implement the March 2008 high flow experiment (HFE) science plan with continued studies of sandbar fate and suspended-sediment transport modeling through 2009
▪ September-October steady flows	Native and nonnative fish monitoring, along with ongoing sediment transport, temperature and specific conductivity	Implement near shore ecology (NSE) Fall steady flow study	Develop and implement NSE/Fall steady flow study
Biological Opinion Conservation Measures			
▪ Humpback Chub Parasite Monitoring	Monitored on 5 year cycle		
▪ Humpback Chub Sediment Research/ Humpback Chub Near Shore Ecology Study		Implement NSE study	--Evaluate backwater habitats and native fish use as part of March 2008 HFE --Fall steady flow experiment
▪ Nonnative Fish Control	Monitoring nonnative fish populations (LCR and mainstem)	Nonnative fish planning and testing	Nonnative removal in FY2009; proposed transfer in FY2010 and beyond to management agency
▪ Humpback Chub Consultation Trigger	Annual humpback chub stock assessment		

Table 1. Summary of the elements of the EA and Biological Opinion Conservation Measures addressed in GCMRC's Monitoring and Research Plan to Support the Glen Canyon Dam Adaptive Management Program, Fiscal Years 2007–11 Cont'd

▪ Comprehensive Plan for the Management of Humpback Chub in Grand Canyon	Provide science support as appropriate	Nonnative fish planning and testing	Nonnative removal in FY2009; proposed transfer in FY2010 and beyond to management agency
▪ Humpback Chub Translocation	- Chute Falls fish monitoring - LCR and mainstem fish monitoring		Chute Falls translocation
▪ Monthly Flow Transition Study	Downstream Integrated QW monitoring, including suspended-sediment transport	Near Shore Ecology study	NSE/ Fall Steady flow science plan
▪ Little Colorado River Watershed Planning	Monitor LCR flows		
▪ Kanab Ambersnail Monitoring and Research	Monitor population status at Vasey's Paradise		
▪ Kanab Ambersnail Habitat Protection			KAS habitat protection during HFE
▪ Southwestern Willow Flycatcher Monitoring and Research	Monitoring Vegetation change in CRE		

Table 2. Strategic science questions from the GCMRC monitoring and research plan (MRP), related HFE science questions, and related HFE experimental studies.

Question	Experimental Studies (Table 3)
Sediment and related resources	
MRP strategic science question: Is there a "flow-only" operation that will rebuild and maintain sandbar habitats over decadal timescales?	
High flow science question: How do conditions of suspended sediment concentration and grain size evolve and vary through time and by reach below Glen Canyon Dam during replication of the 2004 hydrograph under more highly enriched sand supply conditions; and how do these data compare with similar data collected at similar locations during the 1996 and 2004 high-flow experiments? Is the net mass balance of sand following the high flow net positive, negative, or neutral?	1.A
High flow science question: What is the minimum duration for high-flow experiments needed to build and maintain sandbars under sand-enriched conditions?	1B
High flow science question: Can the next high flow increase campable areas at sandbars on a sustainable basis?	1.C
High flow science question: Following a high flow, how do Record of Decision (ROD) operations under 8.23 million acre-feet annual release volumes affect the persistence of sandbars and related backwaters compared to non-ROD operations that followed the 2004 high flow?	1.D
Humpback chub	
MRP strategic science question: How important are backwaters and vegetated shoreline habitats to the overall growth and survival of young-of-year and juvenile native fish? Does the long-term benefit of an HFE outweigh short-term potential costs?	
High flow science question: Do high-flow experiments result in creation of backwater habitats that may benefit humpback chub and other native fishes? To what extent are backwater habitats created by a high flow used by humpback chub and other native fishes?	1.D

Table 2. Strategic science questions from the GCMRC monitoring and research plan (MRP), related HFE science questions, and related HFE experimental studies. Cont'd

Cultural resources	
MRP strategic science question: How effective are various treatments in slowing rates of erosion at archaeological sites over the long term?	
High flow science question: Do sandbars deposited by high-flow experiments contribute to preservation of archaeological sites in the river corridor?	1.C
High flow science question: Do high-flow experiments contribute to added stability or erosion of archaeological sites located in close proximity to the river?	1.C
Strategic science questions: What Glen Canyon Dam operations maximize trout fishing opportunities and catchability? Do rainbow trout immigrate from Glen to Marble and eastern Grand Canyons, and if so, during what life stages?	
High flow science question: How will a high flow affect spawning, survival of early life history stages of rainbow trout (BBT) in the Lees Ferry reach? Will a high flow stimulate downstream migration of age-1 RBT?	4.A, 4.B
Strategic science questions: How is invertebrate flux affected by water quality and dam operations?	
High flow science question: How will a future high flow affect food production and availability for rainbow trout in the Lees Ferry reach? What are the effects of high-flow experiments on aquatic food production? How do these effects impact native fishes?	3
Strategic science questions: How is invertebrate flux affected by water quality and dam operations?	
High flow science question: Will the next high flow result in higher nutrient releases and shrinking of the hypolimnion? Will the operation of the river outlet works and the penstocks at capacity measurably alter Lake Powell hydrodynamics or stratification, or alter release water quality?	5
Strategic science questions: Do dam controlled flows affect rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?	
High flow science question: Are open patches more susceptible to exotic species colonization and establishment than sites with existing vegetation following a disturbance?	2

Table 3. Description of experimental studies included in the HFE science plan and the associated reporting schedule.

Study	Description	Draft Report	Final Report
Sediment, archaeological sites, and backwaters			
1.A. Sand budgeting	Data will be collected to determine the amount of sediment available in the system and its availability for restoring sandbars and camping beaches, patterns of erosion and deposition, and changes in sediment grain size	June 2009	Six months after submittal to journal or December 2009
1B. Eddy-sandbar studies	Data will be collected on the evolution of specific eddy sandbars before, during, and after a high flow. These data may be used to improve the predictive capabilities of the existing sediment model and determine the optimal peak flows of future high-flow experiments.	May 2009 (bathymetric mapping), Dec 2009 (velocity and sediment transport dynamics)	January 2010
1.C. Response of sandbars and select cultural site	Data will be gathered to determine (1) if sandbars throughout the Colorado River ecosystem gain or lose sand as the result of a sand-enriched high flow, (2) if new sand can offset gully erosion, and (3) if enlarged sandbars provide source material for the windborne transport of sand upslope into archaeological sites.	August 2009	January 2010
1.D. Backwater habitats	Measure backwater habitats and sample them for fish in spring and fall to evaluate how (a) backwaters formed by a high flow change over time and (b) how fish, particularly humpback chub, use backwaters.	August 2009	December 2009

Table 3. Description of experimental studies included in the HFE science plan and the associated reporting schedule. Cont'd

Riparian vegetation			
2. Riparian vegetation studies	Study will document changes in riparian vegetation (native versus nonnative) following a high flow to determine if disturbances influence the success rate of nonnative species.	August 2009	January 2010
Aquatic food base			
3. Food availability	Data will be collected to determine how high-flow experiments affect the quantity and quality of food available to invertebrates and, ultimately, fish.	August 2009	January 2010
Rainbow Trout			
4.A. Redds study	Data will be collected to determine how high-flow experiments affect spawning and survival of early-life stages of rainbow trout in Lees Ferry	December 2009	January 2010
4.B. Movement study	Study will collect data to determine if high-flow experiments displace rainbow trout from Lees Ferry and if displacement varies by fish length	December 2008	March 2009
5. Lake Powell	Data to determine if a high flow results in higher nutrient releases and changes in the hypolimnion	December 2008	March 2009
Conservation measures			
6. Kanab ambersnail	To minimize impacts to an endangered species, Kanab ambersnail habitat at Vaseys Paradise will be moved	January 2009	June 2009
Knowledge synthesis			
7. Synthesis of knowledge	Data and knowledge gained as the result of the 1996, 2004 and 2008 high-flows tests will be synthesized in an attempt to address strategic science questions	September 2010 –	December 2010– possibly as an USGS Circular

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Comment Number	Page	Line	Reviewer Name	Affiliation	Reviewer Comments (Be specific	Identify Action Requested	Response Requested	GCMRC Response/Action Taken