TO: Linda Whetton, USBR

FROM: GCD AMP Science Advisors
L.D. Garrett, Executive Secretary, GCD AMP Science Advisors

DATE: January 26, 2005

SUBJECT: Science Advisors Presentation to the AMWG March 2-3, 2005

Following is the text (in bold) that I would like in the AMWG mail out. I have also attached two reports that are to be included.

"L.D. Garrett, Executive Secretary for the GCD AMP Science Advisors (SAs) will present on the following Science Advisor programs:

- SAs completed review of the GCMRC Strategic Science Plan and Core Monitoring Plan
- SA ongoing review of the GCD AMP
- SA assistance to GCMRC in developing improved science integration in research and monitoring programs. This report is informational and does not require approvals by the AMWG.

The GCD AMP Science Advisors are required to formerly report to AMWG on any reviews completed since a previous AMWG meeting.

Completed Review of GCMRC Strategic Science Plan and Core Monitoring Plan: The Science Advisors will report the primary recommendations contained in "A Review of the GCMRC Strategic Science Plan and Core Monitoring Plan" (review attached).

Ongoing Review of the Glen Canyon Dam Adaptive Management Program: The Science Advisors will report on the GCD AMP review currently underway (prospectus attached).

Proposed Science Advisor Assistance Program to GCMRC for Improved Science Integration: The Science Advisors will provide a brief overview of a proposed approach to develop recommendations to GCMRC for improved research and monitoring integration.

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SCIENCE ADVISOR REPORT:

A REVIEW OF THE GCMRC STRATEGIC SCIENCE PLAN AND CORE MONITORING PLAN

GLEN CANYON DAM
ADAPTIVE MANAGEMENT PROGRAM
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NOVEMBER 2004

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INTRODUCTION

The Science Advisors (SAs) have reviewed previously the draft GCMRC Strategic Plan and draft Core Monitoring Plan. These reviews are presented in the June, 2004 Science Advisors Report.

In the initial review, the SAs primary concern with the Strategic Plan was lack of a defined science strategy. An outline approach to a general science strategy was proposed as were other recommendations.

The primary concern with the Core Monitoring Plan was lack of science justification for several areas of monitoring. An expanded write up was encouraged to define current level of knowledge, established relationships, etc. Additional recommendations were also provided.

We are pleased to again be able to contribute to a review of the Strategic Science Plan and the Core Monitoring Plan for the Center. We decided to combine the two reviews, and present a more in depth assessment of the Strategic Science Plan and the linkages between the Strategic and Monitoring Plans. Core Monitoring Plan recommendations are incorporated in discussions of critical science questions proposed in the science strategy.

We applaud the effort of GCMRC to improve the Strategic Plan in the following areas.

- Building staffing capability and rewards systems and evaluating overall staffing needs as regards most appropriate expertise for critical science needs.
- Approaches for developing more proactive collaborative relationships with AMWG, TWG and the SAs on science program development, science application, and budget planning.
- Developing definitive out year science plans, programs, schedules and budgets to insure future stability in program implementation.

We are supportive of the submitted document as a Strategic Management Plan for Science. However, we still would like to propose greater inclusion of specific science strategies. We understand that effort is underway, but we did not receive the revised draft for this review. In that regard, we would like you to consider the following information from our review for potential inclusion in your plan. The information addresses areas of science integration and most critical science questions to be pursued in the next five years. Most important, it proposes more extensive use of integrated ecosystem assessment approaches in pursuit of the proposed questions.

Our position is that the Strategic Science Plan must propose a comprehensive science strategy that pursues ecosystem evaluations, an issue consistently surfaced in science reviews over the last decade. We encourage GCMRC to evaluate the following material and consider it for inclusion as part of the overall Strategic Science Plan for the Center. It is our understanding that some earlier draft proposals from our review are being included in your new revision of the Strategic Science Plan. Hopefully you will also consider these additional recommendations.

We appreciate the willingness of GCMRC to work with the SAs over the next two years to fully evaluate how these strategies can be implemented. We are committed to this process, and are eager to begin initial assessments of progressive procedures for science integration.

GENERAL SCIENCE STRATEGY

The following science strategies will vary over the five year strategic cycle based on the potential changes in science issues being addressed with research and monitoring activities. For example, the current set of research and monitoring activities for FY 2004 and proposed set for FY 2005 are significantly different in several resource areas.

The current effort of AMWG, TWG, GCMRC and the SAs to evaluate and improve all science programs presents an unusual opportunity to revisit all science and science management strategies. Just as new strategies for staffing and outsourcing science are being proposed, the Center needs to also reexamine its science strategies for addressing stakeholder issues, and especially key issues such as humpback chub, cultural resources, science integration, etc.

This restructuring must be formulated with full consideration of the new level of knowledge on such effectors as climate and flows, and the stakeholders reevaluation of priority information needs. It must also consider resource availability to the program.

All of the above factors considered, a science strategy for the next five years should include consideration of new integrated ecosystem science approaches and critical science questions that are more holistic and ecosystem based.

The 1997 GCMRC Strategic Science Plan proposed use of conceptual modeling approaches to guide development of an ecosystem science paradigm for the Center. The strategy proved to be useful in revealing linkages in the ecosystem and identification of key effectors in subparts of the system. However, except for areas of sediment and information technology, these findings have not been fully utilized to establish more integrated sampling designs, and create the necessary space and time dependence of data to conduct more robust ecosystems analysis.

The current increased knowledge level of resource interaction in the CRE and conceptual modeling of these interactions, warrants further use of the modeling approach as a primary strategy for science integration

PROPOSED USGS GCMRC SCIENCE STRATEGY LINKING CORE MONITORING AND RESEARCH WITH INTERDISCIPLINARY APPROACHES

GCMRC has since 1997 significantly increased scientific understanding of resource impacts associated with differing regulated flow regimes from Glen Canyon Dam. And, in collaboration with AMWG and TWG it has invoked adaptive management processes to use this knowledge to enhance resources and also mitigate, as possible, continued impacts to resources. In spite of the continued efforts of AMWG, GCMRC and TWG, resource impacts continue, and some resources, such as humpback chub fish and fine sediments and sand appear to be at extremely precarious levels in the system. These heightened resource concerns have prompted AMWG, GCMRC and TWG to launch extensive science and management planning efforts in fiscal years 2004-2006.

During the next five years the AMP should commit to revaluate accomplishments, establish new and improved science and management directions, and improve resource conditions.

GCMRC, in its contributions to the above direction should commit to new and improved ecosystem science strategies, to assure that information required by AMWG is accurate, current and the most robust that can be made available.

To accomplish this effort the Center should interact with the SAs and other scientist to develop a set of science questions that, when answered, will significantly advance the understanding of resource impacts of differing managed flow regimes, as well as the priority resource issues identified by AMWG. And, because science approaches that evaluate individual disciplines (hydrology, fish ecology) or resources (sand and sediment, rainbow trout) have not provided appropriate answers to more complex ecosystem questions, the Center should also pursue in some programs more integrated interdisciplinary science paradigms. To accomplish all of its programs, the Center should employ a mix of disciplinary (single discipline efforts), multidisciplinary (combination additive process with different disciplines) and interdisciplinary (integrated disciplinary approach) efforts. All these approaches exist in GCMRC programs. However, the interdisciplinary approach, which synthesizes the perspective of the individual disciplines and integrates during all phases of the approach to a question or problem, should have increased application over the next ten years.

INTEGRATED INTERDISCIPLINARY RIVER SCIENCE

The SAs feels GCMRC recognizes the importance of integrated interdisciplinary science as an effective way to study and understand ecosystem complexity. Eugene Odum, the "father of modern ecology," noted that as far as ecosystems are concerned, "the whole is greater than the sum of its parts," and as such, reductionist scientific methods alone cannot adequately explain living systems. Few would argue that one of the traits of an ecosystem is its incredible complexity and
'a bewildering array of interconnections between all the individual components that make the whole.

River science is by its very nature fundamentally interdisciplinary. Answering the most critical freshwater problems of our times requires integrating socio-cultural and biophysical concepts and methods. Flow, dissolved and suspended materials, and living resources within the river channel all interact. As emphasized in a recent internal USGS (2004) white paper, river science today transcends conventional disciplinary boundaries because “*the hydrologic cycle, in concert with human activities and geological, biological, chemical, and climatic processes, controls most of the commonly recognized features of rivers, such as river form, seasonal variations in flow, chemical quality, and the type of living resources in rivers.*”

The SAs feel GCMRC is poised to meet this challenge and provide pioneering work and leadership in the arena of integrated river science. GCMRC is already well along the path to integrative research in many areas. An integrative river science approach should support society’s broad concerns on how to best manage and sustain competing goods and services of rivers to benefit both humans, and the natural ecosystems to which humans belong. This means that single resources (and their research programs) are not studied in isolation from other resources or from the socio-cultural context. Further, truly integrative river science should aim to both understand and ultimately predict how rivers respond to human activities and outside forces such as climate variability. Human activities include, for example, flow regulation, water extractions, land use alterations and recreational use. Understanding will come from the developed integrated Monitoring Program and Long Term Experimental Program. Prediction comes from a synthesis of findings in a quantitative framework.

TRANSITIONING TO INTEGRATED INTERDISCIPLINARY SCIENCE

First, the Center’s Strategic Science Plan is the foundation upon which all monitoring and research efforts arise. The purpose of this plan should be to identify the critical research questions of the time. The phrase “of the time” is used because priority areas will change over time (e.g., due to droughts, endangered species status, etc.), and the science plan must be adaptive like management.

Second, all members of each research team (e.g., physical, biological, cultural) should together develop a conceptual model that illustrates the information needed to answer each highly prioritized question. Some of this information will be core monitoring and some will be research. Such models are critical to identifying knowledge gaps and scientific directions. Some of the high priority questions may be answerable using the theories and methods from single disciplines, but justification to do the work must be made in the context of the entire Strategic Science Plan. The vast majority of the high priority questions will require input from multiple disciplines.

Third, the science needs (type of information) should be identified along with interdisciplinary teams that will gather the data. This should result in a list of core measurements and/or research tasks along with a timetable for each priority question. The challenge is to determine which "keystone" components of the almost infinite number of measurable physical, chemical and biological parameters in a river system should be studied to most comprehensively evaluate the interrelationships among them in the river ecosystem.

Fourth, team leaders should be identified for each priority research question. That person does not represent his/her area (physical, biological, cultural resources) but is responsible for making sure all the information that is needed to answer the critical question is gathered and the time line adhered to. This person also is responsible for the collation, analysis, and interpretation of the data which must result in written reports to AMWG as well as management guidelines.

SPECIFYING GCD AMP CRITICAL SCIENCE QUESTIONS

GCMRC, AMWG and TWG have over the past seven years brought focus to the most critical science issues for the GCD AMP. Further, AMWG has maintained a continued effort at articulating specific information needs for science inquiry. Because of these efforts, the following science questions identified and posed by the Science Advisors should also address the critical information needs of the stakeholders.

The Science Advisors propose the following general science questions be engaged over this strategic plan period i.e., five years. Greater specificity on each question is provided in this section.

Question: How does the CRE and Lake Powell respond to drought and climate stressors?

Need/Rational: Historically, Lake Powell has acted to minimize the seasonal and longer-term climatic variability that occurs in the physical and chemical characteristics of the Colorado River. As a result of water being released from well below the surface of the dam, the water leaving Lake Powell has been relatively stable with respect to temperature and nutrient concentrations. However, as the current drought continues and the water level in Lake Powell drops, these relatively stable conditions have and will continue to change. As the water level drops and the thermocline in the lake approaches the depth of withdrawal, water temperatures leaving the dam are increasing.

Increased water temperatures and the possible associated decrease in nutrient concentrations could impact the food base, the movement of warm water fish upstream, and the magnitude of disease and parasites. Changes associated with the current drought can be used to help predict the changes that may be expected with a temperature control device and other future long-term droughts. There is a need to be able to understand the effects of the recent drought, possible long-term climatic change, and climatic variability.

Approach: Direct effects of the drought and climatic variability on the hydrology upstream of Lake Powell are currently monitored by agencies outside of the GCMRC. The Bureau of Reclamation monitors the climatic conditions throughout the Colorado River Basin and the USGS, Water Resource Division,(WRD) monitors the streamflow of the major tributaries near to where they enter Lake Powell. The GCMRC should encourage these agencies to conduct water-quality sampling (at least water temperature, conductivity, and nutrient concentrations) at the streamflow monitoring sites on these tributaries. The direct effects of climatic variability, including the present drought, on the physical and chemical conditions in Lake Powell, including the forebay, can be evaluated using the GCMRCs monthly sampling of the forebay and quarterly sampling throughout the lake. To determine if the climatic effects and the effects of varying water level on Lake Powell are properly understood, the BOR CE-QUAL-W2 model should be used to simulate the recent drought and the output from the model should be compared with recent data collected in the lake.

Changes in water temperature that occur as water moves down the canyon is measured at various locations; however, changes in nutrient concentrations are not presently included in the program. The BOR is in the process of developing a sub program in the dynamic model (CE-QUAL-W2) to simulate the changes in water quality as the water flows downstream. GCMRC could collaborate on a more aggressive schedule for model development.

Changes in the hydrology, water temperatures, and nutrient concentrations downstream of the dam will significantly impact the Grand Canyon ecosystem. This information can be used to predict changes that may occur with the implementation of the temperature control device and what could occur in future long term droughts. These changes include, but are not limited to, changes in metabolism throughout the river, changes in Rainbow Trout and Humpback Chub recruitment, changes in the food base, etc. To examine all of the impacts of the drought requires input from all of the disciplines within the GCMRC and, therefore should be used to foster interdisciplinary collaboration. Specific monitoring needs for these other key questions are discussed elsewhere.

Time Frame: It is proposed that the five year period of this plan is needed to understand the effects of the current drought, however, the effects of climatic variability will take many years to decipher.

Core Monitoring Needs: Core Monitoring projects are referenced to letters and numbers for specific programs in the Core Monitoring Plan, (CMP) i.e., A.1, B. 2.

- Forebay (A.1). Monthly sampling of temperature, conductivity, dissolved oxygen, phosphorus (dissolved and total), nitrogen (nitrate, ammonia, and Kjeldahl), dissolved and particulate organic carbon, and chlorophyll are needed**.**
- Dam outlet (B.2). Continuous temperature, conductivity, and dissolved oxygen. Samples should be routinely collected and analyzed for nutrients and dissolved and particulate organic carbon.
- Streamflow (A.2 and B.1). Measurements should be collected at the dam, several mainstream stations, and near the outlets from the Little Colorado River and Havasu Creek.
- Water Quality (B.2). Routine measurements should be taken (at least monthly) at a subset of the gaging stations (but including the key locations on the mainstem and at the Little Colorado River and Havasu Creek) for sediment, and **nutrients.**
- Meteorological monitoring. Basic meteorology in Lake Powell (raft station), and selected information in the canyon required for CE-QUAL-W2 (possibly associated with aolean transport processes) will need to be developed.

Research Needs: Several areas of research needs exist, as follows.

- Modeling (physics and chemistry) of Lake Powell with CE-QUAL-W2 by the BOR.
- Modeling (physics and chemistry) of mainstem Colorado by GCMRC (empirical modeling) and by the BOR (dynamical modeling with CE-QUAL-W2 by the BOR).
- Additional sampling and assessments of selected pollutants should occur in the Little Colorado River and Havasu Creek to establish a baseline for which to compare future measurements. This kind of sampling can be done every few years.

Question: How will recent changes in water temperature affect distribution and trophic interactions of native and exotic fishes?

Question: How will HBC and RBT respond to varied flows, temperatures, and population?

Question: How do CRE biotic resources such as humpback chub (HBC) and rainbow trout (RBT) respond to changes in water quality?

Need/Rationale: This issue is of immediate relevance in two respects. First, the proposed development of the Temperature Control Device (TCD) at Glen Canyon Dam is moving forward to the implementation phase. GCMRC and BOR have given extensive consideration to its potential. Dropping water levels during 2004 put the Lake Powell metalimnion at the depth of GCD penstocks and river water now warms in response.

Approach: Temperature monitoring and prompt reporting of results are essential in this year and the next several years of low lake levels. So, too, are the distribution and numerical responses of key biological resources such as the humpback chub, its prey resources, competitors and predators as well as rainbow trout. Those should evoke immediate attention to the adequacy of ongoing monitoring efforts. Special attention should be directed to effects on rainbow trout below the dam, the ongoing removal of exotics above and below the LCR and recruitment success of HBC at the LCR. Other concerns include the upstream migration of brown trout from the Bright Angel region, plus similar responses of coolwater fishes (e.g., walleye) and warmwater fishes (e.g., striped bass, smallmouth bass, common carp, and channel catfish) advancing from the lower river reaches and Lake Mead. These prospects call for a much more aggressive pursuit of current modeling approaches that incorporate the recent responses as a calibration process.

Time Frame: Ongoing monitoring projects must assure that appropriate measures are in place right now and for the immediate future. Budget allocations should emphasize quickly-mobilized research support for modeling efforts that accelerates understanding of future scenarios based on promptly-reported results in hand. One scale of modeling endeavor can focus on bioenergetics models for individual fish species. A second scale could develop increased climate effects in the food web represented by the Walters and Kormann model of the CRE. Both modeling approaches are currently in hand and can quickly be put to appropriate uses.

Monitoring Needs: As outlined in the Core Monitoring Plan (Sections B.3, B.6 and B.7), work pertinent to this issue is in place and/or intended for fishes in the mainstem (e.g., rainbow trout) and the LCR (e.g., humpback chub). Work on fish diets, growth rates, abundance and distribution are directly pertinent. Surveys for non-native fishes are directly pertinent but may be expanded to improve sensitivity to upstream migrations and surrogates (catch per effort) for abundance.

Research Needs: New efforts in modeling must be advanced promptly. Those are:

- A bioenergetics modeling effort can adopt the models currently available for many native and non-native fishes. Those exist for humpback chub (Petersen et al., in review), and a representative set of the non-native species (e.g., rainbow trout, brown trout, striped bass, smallmouth bass and walleye). The latter are presented in Hanson et al. (2001). Inputs for these models must come from GCMRC staff. Those include diet data, temperature histories, growth rates and scenarios of future thermal conditions. In the absence of direct evidence for thermal effects on food base production rates, modeling strategies should be based on two general hypotheses: A. That prey production rates increase in proportion to temperature changes, and B. That prey production rates are fixed due to food web constraints of fixed nutrient availability. Those can be used to bound the prospects for changing prey consumption rates and envision the range of effects owing to higher mortality rates due the thermal effects and changing abundances.

- Ecosystem-level responses to long-term climate warming can be evaluated through extension of the Walters et al. modeling effort. System responses to warming and the TCD prospect(s) can be estimated owing to temperature effects on each trophic level. Climate change scenarios can derive from results of global climate model(s) and their general predictions for the southwest region of the US. We note that some modeling forecasts of climate change include greater precipitation rates for the region (IPCC forecasts).

In keeping with the "deductive engine" approach, results of these modeling efforts can produce a better focus on necessary modification of monitoring efforts and the next suite of pertinent research issues. We emphasize the obvious merits in collaborative, integrated effort as, for example, in use of remote sensing to monitor and model water temperatures, modeling of Lake Powell physical limnology as the basis for estimating water temperatures at the penstocks, and attention to the results of stable isotope assessments of food web interactions.

Question: What Are the Food Base Requirements for HBC and RBT?

Need, Rationale: Critical to stabilizing the HBC population in the canyon is a clear ecosystem level understanding of the effects of the food base on the HBC and RBT population. Because there is substantial diet overlap between these two species and they are both of concern to multiple groups, we must determine what their primary food resources are and how dam operations influence those resources.

Approach: The historic focus of the food base research has been on biomass and standing stocks (algae, invertebrates). However, their huge variability over space and time made it impossible to make inferences on the status and trends of the food base. Therefore, the recommended approach is to immediately begin:

- A stable isotope analysis that would identify the energetic base (allochthonous, autochothonous) in this system and serve to guide core monitoring for the food base program. Isotopic signatures of the HBC and RBT combined with food gut analyses can tell us if the primary basal resource that supports these fish is algae or detritus and how this varies from Lees Ferry to the LCR. Note: The purpose here is *not* to develop a predictive model between food levels and fish but to use this tool to determine what aspect of the food base the fish rely on so that long term monitoring of those aspects can be begun quickly.

- Begin collecting water and suspended sediment samples at multiple points along the river for analysis of chlorophyll and nutrients: carbon (DOC and POC), nitrogen (DIN, DON), and phosphate phosphorus. This serves the dual purpose of providing a water quality monitoring baseline for pre TCD deployment and should allow for the future development of a carbon budget, which ultimately is necessary for determining if food limitation is an issue.

Time Frame: Spring 2005: 1) Begin collecting water for nutrient analyses. This is routine work done in virtually all water monitoring programs; 2) Develop data management protocol for getting nutrient data online rapidly so that stakeholders can go to the web site and not only see temperature data but nutrient data; and, 3) develop protocol for integrated (across physical science and biological science programs) suspended sediment sampling and analyses to meet the needs outlined in sediment budgeting..

Summer 2005: Collect algal, detrital, and fish samples for stable isotope analyses and send these out for analyses; interpret results using appropriate mixing models.

Fall 2005: Implement the Integrated Suspended Sediment Sampling & Analysis Protocol.

Core Monitoring Needs: Replicate measurements at preset points along the river (from Lees Ferry to at least and below LCR) on a seasonal basis and in response to major flow/sediment events.

- Water samples to analyze for carbon (DOC and POC)
- Water samples to analyze for total nitrogen (DIN, DON)
- Water samples to analyze for total phosphorus. Note: This requires filtered and unfiltered samples, as much of the phosphorus will be bound to suspended sediments.
- Suspended sediment samples slated for combustion (to measure organic carbon)

The measurement of nutrient concentrations described above as top priorities should be added to CMIN#7.2.1 of the Core Monitoring Plan (Page 21, Table B.2.1,). At minimum, measurement of the same nutrients that are currently being monitored at -15 and 0 river miles should be immediately begun and extended to river miles 30, 61, 87, 166, and 226. At the time water samples are collected for suspended sediment concentration (monthly at river miles 30, 51, 87, 166, and 226) additional water should be collected for biological analyses outlined above. This is likely to require preservation (chemical additions to sample bottles) for later biological analyses in the lab. The need for measurements of nutrients along the stream corridor are identified in the Draft Core Monitoring Plan under section 2.2, Part B.2 (page 36) but the top priority nature of this was not reflected in the core monitoring plan.

Research Needs: Research will focus on stable isotope and fish tissue analysis. Stable isotope analyses will assist in determining food base for HBC and RBT. Standard Protocols already exist for this type work. The Center will have to collect algal, detrital, and fish tissue samples and send them off for analysis at a stable isotope lab that routinely does this work (e.g., Ehleringer isotope lab, University of Utah).

- Additional possible research: fish tissue samples can be collected from museum specimens so that pre-dam isotope signatures could be examined. Apparently this is also now done routinely (e.g., vander Zanden, Univ Wisconsin).

With respect to the research needs (stable isotope) that will determine the core monitoring needs for the food base, the Draft Core Monitoring Plan indicates that a "future cooperative agreement [to plan a Food Base Initiative] will be developed and solicited for in September 2004" (page 42). The Science Advisors are not aware that such an effort has occurred, although it was recommended in a previous review. Additionally, the time line indicated for getting a core monitoring program for the food base in place is stated in the draft plan at 4 – 5 years (page 42). This is much longer than is needed. This is routinely done by differing institutions, and can be solicited by an RFP. The SAs would be more than willing to review an RFP for this work.

Question: What comprehensive cultural resource strategy is most appropriate for FY 2005-2009?

Question: How can flow impacted cultural site resource loss be best mitigated in FY 2005-2009?

Need/Rationale: First, it is necessary to recognize that it is more important that a plan for managing cultural resources be in place prior to developing a plan for treating cultural resources of the Colorado River and the Grand Canyon National Park. And, it is necessary that the Grand Canyon Monitoring and Research Center or another GCD AMP entity coordinate the development of a Historic Preservation Plan (as called for under the National Historic Preservation Act) rather than continuing to operate in an ad hoc fashion under the Monitoring and Remedial Action Plan of the 1994 Programmatic Agreement.

Second, it appears that there is no single agency proposed to move all needed program activities forward. For example, the National Park Service recognizes its responsibilities under Section 110 of the National Historic Preservation Act to develop a historic preservation plan for the "identification, evaluation, and nomination" of historic properties within the areas of its responsibility. The Bureau of Reclamation recognizes its responsibilities under Section 106 of the National Historic Preservation Act to evaluate the impacts of its undertakings on historic properties within the area of potential effects. However, in spite of this recognition by the two agencies, there is no single authority specified for integrating the information on the cultural resources and evaluating the impacts of the various federal agencies' programs on them. Finally, while not required under the National Historic Preservation Act, the National Park Service continues to monitor impacts to National Register properties under the Monitoring and Remedial Action Plan of the 1994 Programmatic Agreement. This information should be used to develop a program that could prove beneficial to the long-term protection of monitored sites and other threatened properties in the Grand Canyon.

As a result, of the above concerns, it appears that three major deficiencies exist within the program as it currently stands, which GCMRC could potentially coordinate, if supported by the NPS and BOR.

1) Developing a Historic Preservation Plan to guide the management of cultural resources within the Grand Canyon National Park;

2) Getting a federal agency recognized as being responsible for the over-all treatment of cultural resources within the Canyon; and

3) Integrating information from the monitoring program into an applied program that could be beneficial to threatened historic properties within similar environments in the Canyon.

Time Frame: The proposed time line, by necessity, is overly general in nature, and offers suggestions for implementing important aspects of the Socio-cultural Program. It is also implicit that these tasks be undertaken simultaneously rather than sequentially.

FY 2005 – Develop the Historic Preservation Plan. Initiate the determination/recognition of a federal agency as the lead agency.

FY 2006 – Develop Mitigation/Archaeological Data Recovery Plan to mitigate the impacts of the undertaking on threatened historic properties.

FY 2007 – Initiate Mitigation/Archaeological Data Recovery Plan.

FY 2008 – Continue Mitigation/Archaeological Data Recovery Plan.

FY 2009 – Continue Mitigation/Archaeological Data Recovery Plan.

The Historic Preservation Plan should be developed immediately and the SAs will gladly assist in its review once it is developed. It is imperative that a lead agency from among the National Park Service, the Bureau of Reclamation, or the Grand Canyon Monitoring and Research Center be identified for this effort as soon as possible so that historic properties and traditional cultural properties within the Grand Canyon/Colorado River ecosystem can be properly protected. In order to meet responsibilities required under the National Historic Preservation Act to mitigate the impact of the undertaking on historic properties, the GCMRC must develop a Mitigation/Archaeological Data Recovery Plan relating to historic properties within the area of potential effect rather than continuing to rely on the current Monitoring and Remedial Action Plan of the 1994 Programmatic Agreement. Such a Mitigation/Data Recovery Plan will provide a means of mitigating the impacts of the undertaking on historic properties as well as continuing to monitor the effects of sediment removal, intermittent beach habitat building episodes and other such programs currently undertaken by the GCMRC.

Monitoring and Research Needs: As a prelude to the following discussion, it is necessary to note that the Archaeological Site Monitoring Plan, as presented within the September 24, 2004 Draft Core Monitoring Plan, presents proposed elements of a future plan rather than presenting a proposed plan. It also shifts responsibility for developing a set of core monitoring protocols for cultural resources to an independent PEP.

The proposed elements presented within the Draft Core Monitoring Plan seem to capture much of the primary concerns related to impacts of the continued dam operation on National Register-eligible cultural resources direct and indirect impacts of dam operation on the physical environment of the archaeological sites (sand deflation, arroyo erosion, visitor impact), site integrity issues, physical impacts on traditional cultural properties, etc. As such, it contributes to the long-term tracking of the physical impacts of continued dam operation on cultural resources within the area of potential effect.

The positive side of the proposed plan is the attempt to partner with existing programs within the GCMRC as a means of capturing data that might be beneficial in the long-term monitoring atmosphere, such as the utilization of meteorological stations in conjunction with the collection of wind data as a means of understanding the impact of local conditions on the physical environment of the archaeological sites.

Problematic, however, is the continued operation of a monitoring program in the absence of a formal Historic Preservation Plan guiding the long-term management of the cultural resources. The current Socio-cultural Program is aimed at protecting archaeological sites in their physical and cultural settings rather than on mitigating impacts to the sites in ways other than physical protection, such as through data acquisition, archaeological site excavation, etc. Information on physical impacts is currently being collected, but that information is not being integrated in such a way that the results can be applied in a programmatic manner throughout the Grand Canyon. The absence of an integrated research design driving the program makes the accumulation of data an exercise in "sciencing" rather than a scientific exercise.

The primary concerns related to the proposed Core Monitoring Plan follow:

- There is no true Core Monitoring Plan, *per se*, but rather a listing of elements that should be considered to be a part of one, once it is developed.
- The proposed plan continues to rely on the measurement of physical changes within archaeological sites in the Grand Canyon, but offers no method or suggestion for integrating that information for predictive capabilities, and continues to operate without programmatic guidance.
- The proposed Core Monitoring Plan does not take into consideration the manner in which the historic preservation plan would influence the range, depth, and focus of the monitoring program.

It cannot be emphasized strongly enough that the primary focus of the Socio-cultural Program in the most immediate future should be in developing the Historic Preservation Plan (or at least programmatic research designs) that can be used to guide the long-term monitoring plan as well as the management of the cultural resources to which that monitoring is applied.

The following recommendations seem appropriate for potential monitoring, research and administrative management.

- Immediately develop, in conjunction with the National Park Service, the Bureau of Reclamation and appropriate tribal groups, a Historic Preservation Plan so as to complete the plan by the end of FY 2005.
- Develop a Mitigation/Archaeological Data Recovery Program as an over-all research design that allows for the proper management of cultural resources.
- Integrate the results of the current long-term monitoring program with other GCMRC programs so as to insure that information links the impact of flow regimes on the cultural resources via modeling or other appropriate techniques.

Question: What flow regime strategies best maintain fines and enhance and maintain beach areas?

Question: How are sediment fines routed and stored through the CRE under differing flow regimes?

Need/Rational: The post-dam change in river regime has severely reduced fine sediment input to the river (~93% reduction)**.** Effects of this include 1) Reduced turbidity, with implications for fish survival, 2) decrease in bed cover by fine sediments, particularly in Glen Canyon reach and above LCR, and 3) erosion of beach sands at and above level of normal fluctuating flows.

Approach: Continue research and monitoring of fine sediment transport and storage and develop management strategies. Sediment transport and sand inventories have been a priority for research and monitoring for a number of years. The system is reasonably well understood based upon 1) long-term monitoring of the geographic distribution of deposits using a variety of techniques, 2) monitoring of suspended sediment concentration along the mainstem and in tributaries, 3) studies of the effects of experimental flows, and 4) theoretical modeling and laboratory experiments

An adaptive management strategy of short-duration beach-building flows following sediment input from the Paria River has been initiated, but to date not implemented due to lack of sufficient sediment input. Contingent beach-building flows should continue to have a high priority.

- Study of possible long-term sediment augmentation should be conducted including assessment of beneficial effects from increased turbidity and increased sand supply for bed and beach rebuilding. In addition, potential negative effects should be assessed, including effects at source sites, pollutants, and costs relative to benefits. This might be implemented in a staged fashion, with initial assessment within a two-year period and an in-depth study based upon initial findings.

Core Monitoring Needs: Core Monitoring protocols relating to fine sediment include:

- 2.1.B.1. Surface Water Measurements (stage and discharge)
- 2.1.B.2. Quality-of-Water Measurements
- 2.2.B.4. Fine Sediment (Sand and finer) in the Aquatic Zone (below 25,000 cfs)
- C.1. Fine Sediment in the Terrestrial Zone (above 25,000 cfs)
- 3.B. Remote Sensing

Monitoring of the fine sediment budget should be continued and further developed with regard to new technologies and implementation procedures, but possibly at a reduced level of effort and frequency. Possibilities for more efficient sediment monitoring include:

- Fewer monitoring sites for measuring sand volumes and/or less frequent resurveying.
- Less frequent collection of physical samples of suspended sediment, with greater reliance on automated turbidity measurements.
- Less frequent routine collection of images and topography from overflights.

Development of a sampling and sand inventory survey protocol is needed that is partially event-triggered, such as after major tributary floods (e.g. floods with >5 to 10 year recurrence interval), with less frequent resurveys or samples during normal dam release periods. However, the number of sediment concentration measurement sites should not be reduced. A provision should be included in either the core monitoring or research budgets to permit sediment sampling and sand inventory surveying after experimental flows.

Sediment sample collection should be integrated with biological monitoring needs for organic sediment components as well as total and dissolved nutrients. These new core monitoring needs should be implemented immediately.

Core monitoring related to the occurrence and budget of coarse sediment should have lower priority than fine sediment monitoring. Sampling intervals could be reduced in spatial scope, time of initial implementation, or temporal frequency of observations. These include:

- 2.2. B.5. Coarse Sediment in the Aquatic Zone (below 25,000 cfs)
- C.2. Coarse Sediment in the Terrestrial Zone (above 25,000 cfs)

Research Needs: Research is needed in both fine sediment modeling and sediment augmentation. Development of a predictive fine sediment model should continue, perhaps at a reduced level after 2 years. Model development should result in a computer program that can be queried for such issues as: 1) Long-term effects of Glen Canyon Dam; 2) effects of tributary floods on sand volumes and sediment availability for beach building flows; 3) estimated size and a real coverage of bed sediment (sand and gravel); and 4) effects of possible future sediment augmentation. This program should be able to distinguish between effects within different reaches of the river, such as above Lees Ferry, within Marble Canyon, the open reach below the Little Colorado River, etc. The program should be targeted for completion by 2006 and no later than 2008. A continuing budget item should be included for validation of the model with new sediment data.

Question: How are Riparian and Spring Plant Communities and Habitats Effected by Flow Regimes?

Question: How does the occurrence and state of marsh and backwater communities associated with different flow regimes affect fish reproduction and survival?

Need/Rational: The Management Goal states "protect or improve riparian and spring communities within CRE, including T&E species and their critical habitat." We propose research and monitoring priorities for the next five years, including

- Investigations must determine how the occurrence and state of marsh and backwater communities formed under differing flow regimes affect fish reproduction and survival. The question requires an integration of aquatic resources research and terrestrial habitat. It could include addressing the importance of terrestrial (allochthonous) inputs to food base in some backwaters. It is less important to strive for statistical rigor than it is to determine if this is an important aspect of CRE aquatic ecosystems related to flow regimes.
- Monitor the status of seeps, springs, and related plant communities, including the Kanab Amber Snail and their association with differing flow regimes.
- Evaluate remote sensing technology to track the encroachment of non-native and native vegetation onto recreation sites under alternative flow regimes. This is a combination of research and monitoring to determine how to interpret remotely-sensed information. The approach should present field truthing to be reduced to a 5 year interval.

Approach: This section draws from CMP information needs B.3, B.4, C.1, C.3., C.5, and C.7). There are important elements of the terrestrial vegetation program that need to be continued and integrated with the rest of the critical needs. These are discussed below. Some on the ground measurements will need to be continued at a much lower frequency. Core monitoring and research are suggested below to aid in the understanding of how under differing under differing flow regimes the terrestrial ecosystem may affect aquatic resources of the CRE, the state and condition of the KAS and its habitat, and the affect of vegetation encroachment on campsites and the subsequent influence on recreational experience.

We recommend a focused and integrated approach to riparian vegetation that is directly tied to the above prioritized research questions related to aquatic resources, as follows.

Core Monitoring Needs: Core Monitoring information can be satisfied from:

- CMIN 6.1.1. Determine and track the abundance composition distribution and area of marsh communities as measured at 5-yr or other appropriate intervals based on life cycles of species and rates of change. Rates of change should be measured with remote sensing.
- CMIN 2.4.1. Determine and track abundance and distribution of non-native fish species (although element does not describe specifically the marshes and backwaters).
- CMIN 2.6.1 Determine and track abundance and distribution of flannelmouth sucker, blue head sucker, and speckled dace populations in CRE (especially breeding or feeding sites).

Research Need: To answer a sub-question, "Is riparian vegetation an important contributor of carbon resources to the aquatic food base", will require research sampling of organic material, stable isotope analyses of algae, leaf litter and other detritus, invertebrates and fish.

Question: How are springs and seeps and their communities, including Kanab Amber Snail (KAS), related to flow regimes?

This question and the following recommended question are supported by specified monitoring approaches in the CRP. However, changes are recommended in sampling intensity and approach.

Core Monitoring Needs:

- CMIN 5.1.1 Monitoring of this information need will determine and track abundance and distribution of KAS at Vasey's Paradise in lower and upper zone. We recommend sampling at less frequent intervals than the twice yearly identified.
- CMIN 5.2.1Determine and track size and composition of habitat for KAS at Vasey's Paradise. We recommend sampling frequency be reduced.
- CMIN 6.6.1. Determine and track composition, distribution, abundance of seep and spring communities.

Question: Is the encroachment of native and non-native vegetation onto recreation sites related to flow regimes?

Core Monitoring Needs: The following monitoring studies provide data for this question.

- CMIN 6.5.1. Determine and track abundance and distribution of non-native species in CRE (using remote sensing at the proposed four-year schedule)
- CMIN 8.5.1 Track, as appropriate, the biennial sand bar area, volume and grain size changes above 25,000 cfs stage, by reach.
- CMIN 9.1.1 Determine and track the change in recreational quality, opportunities and use.
- CMIN 9.3.1 Determine and track size, quality, and distribution of camping beaches by reach and stage level, remote sensing
- CMIN 9.3.2 Determine and track ROD operations on size, quality and distribution of camping beaches in CRE using remote sensing

Research Needed: The following research should be accomplished

Conduct research to match remotely-sensed vegetation with field surveys.