THE GRAND CANYON MONITORING AND RESEARCH CENTER

LONG-TERM MONITORING AND RESEARCH STRATEGIC PLAN

by

GRAND CANYON MONITORING AND RESEARCH CENTER

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LONG-TERM MONITORING AND RESEARCH STRATEGIC PLAN

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EXECUTIVE SUMMARY

INTRODUCTION

This Long-Term Monitoring and Research Strategic Plan (the Strategic Plan) is designed to implement the adaptive management and ecosystem science approaches called for in the 1992 Grand Canyon Protection Act (GCPA), Glen Canyon Dam Environmental Impact Statement (GCDEIS, 1995) and the Record of Decision (ROD, 1996). The monitoring, research, and information technology activities outlined for physical, biological, cultural and socioeconomic resources will be implemented over a five-year period. Within each of these years, an annual monitoring and research plan will be developed to assure appropriate progress on critical elements of the Strategic Plan.

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All elements of the Strategic Plan, and all monitoring programs, research projects and information technology activities drafted into annual plans will incorporate the ecosystem science paradigm and be developed cooperatively with the Adaptive Management Work Group (AMWG), utilizing adaptive management procedures. All programs proposed will relate to determined or potential resource impacts primarily in the Colorado River corridor between Glen Canyon Dam and Lake Mead resulting from “The effects of the Secretary’s actions.”[2]/

The Strategic Plan and annual monitoring and research plans will build upon the rich history of monitoring and research investigations developed by the Bureau of Reclamation (BOR) and other organizations. Although the first scientific efforts in geomorphology, biology and ethnography in the Canyon were developed by John Wesley Powell in 1869, the majority of scientific accomplishment in the Colorado River corridor between Glen Canyon Dam and Lake Mead has been accomplished under the guidance of BOR since 1982. Since that time, the BOR Glen Canyon Environmental Studies Program (GCES) has initiated a significant number of research studies and monitoring activities to determine baseline conditions and associated change in many physical, biological, cultural and socioeconomic resources.

Over a period of thirteen years, the GCES and other agencies and research entities developed extensive databases in many different resource areas. Further scientific analysis in many of these areas permitted identification of some of the important attributes associated with changes

[2]/As specified in the 1992 Grand Canyon Protection Act, the Glen Canyon Dam Environmental Impact Statement (1995), and the Record of Decision (1996). The “Secretary’s actions” include dam operations or alternative dam operating criteria as well as other authorized actions.

in critical resources. Significant opportunity now exists to conduct state-of-the-science assessments of these collected data and research to improve understanding of critical attributes affecting specific resources and the interrelationships of resource attributes in the riverine corridor.

Independent reviews of past research in the Colorado River corridor primarily between Glen Canyon Dam and Lake Mead have concluded that several actions are necessary to ensure progressive future monitoring and science programs . These include:

1. Implementation of an adaptive management process to facilitate close interaction of science and management in applying new management criterion and evaluating the impacts of those criterion.

2.Development of a conceptual model of the Colorado River ecosystem primarily between Glen Canyon Dam and Lake Mead to define critical attributes within resource categories, critical attribute linkages across resource categories, and interdependencies of resource attributes.

3.An extensive synthesis and state-of-the-science assessment of all past knowledge associated with predam baseline resource conditions in the Colorado River ecosystem primarily between Glen Canyon Dam and Lake Mead, riverine resource changes associated with construction of the Glen Canyon Dam, and changes associated with “the effects of the Secretary’s actions.”

4.Ecosystem analyses to improve understanding of the most critical attributes thought to be drivers of change of individual resources and groups of resources, and the interdependencies of attributes within and across resources.

5.Development of predictive models of ecosystem function and interaction.

MISSION AND SCOPE OF GCMRC AND THE STRATEGIC PLAN

The GCPA and GCDEIS direct the Secretary of Interior, "To establish and implement long-term monitoring programs and activities that will ensure that Glen Canyon Dam is operated in a manner consistent with that of Section 1802" of the GCPA.

The mission of the Grand Canyon Monitoring and Research Center (GCMRC) is to develop and implement long-term monitoring and related research activities to determine "The effect of the Secretary's actions" on the natural, recreational, and cultural resources of Grand Canyon National Park and Glen Canyon National Recreation Area, as well as other information needs specified by the AMWG. The GCMRC will work cooperatively with the AMWG, utilizing an adaptive management process and implementing monitoring and scientific investigations within an ecosystem science framework.

Long-term monitoring will occur on all resources of concern, to determine changes in resource attributes. Research will be used to interpret and explain trends observed from monitoring, to determine cause and effect relationships and research associations, and to better define interrelationships among physical, biological and social processes.

In addition to monitoring and research activities, the GCMRC will develop information technologies to assure information archiving and transfer to managers and stakeholders and science organizations. Specific protocols will be developed to ensure sensitive information such as location of endangered species and cultural resource sites are maintained in confidence.

More specifically, the geographic and institutional scope of the long-term plan is limited to the natural, cultural and recreational resources within Grand Canyon National Park and Glen Canyon National Recreation Area affected by actions taken by the Secretary through the GCPA and GCDEIS, including modifications to plans and operating criteria for Glen Canyon Dam. The physical scope of the program includes primarily the Colorado River mainstem corridor and associated riparian and terrace zones from the forebay of Glen Canyon Dam to the upper reaches of Lake Mead, identified as Glen Canyon National Recreation Area and Grand Canyon National Park, a distance of approximately 293 miles. The research scope includes limited investigations into side tributaries such as the Little Colorado and Paria Rivers. It also includes resource impacts to inundation levels associated with a flow of 100,000 cfs from the dam.

An assessment of water quality in Lake Powell will be completed in FY97, and any future monitoring and research investigations in either Lake Powell or Lake Mead is currently being designed as being associated with impacts resulting from “The effects of the Secretary’s actions.” In general, resource impacts may result from “The effects of the Secretary’s actions” as specified in the GCPA, GCDEIS, and the ROD, and/or identified for evaluation by the AMWG.

STAKEHOLDER INFORMATION NEEDS AND CRITICAL RESOURCE ATTRIBUTES

The Strategic Plan is by design established to respond to the general objectives and information needs of managers and stakeholders regarding the Colorado River corridor and its resources. Objectives and information needs of stakeholders are specified in nine different resource areas including hydropower, water, sediment, fish and aquatic, biology riparian vegetation, threatened and endangered species, terrestrial wildlife, cultural, and recreational resources.

Within each of the above resource areas specific objectives have been developed cooperatively by the BOR and representatives of the AMWG, and are reviewed in the text of the Strategic Plan and specified in Appendix A[3]. Detailed information needs for specific objectives and resource areas were then defined by representatives of the AMWG working cooperatively with the GCMRC. These are also presented in the text of the Strategic Plan and Appendix A. Objectives and information needs specified by stakeholders are the basis for development of both monitoring and research programs, and these are referenced in the Strategic Plan when discussing monitoring and research programs.

ENSURING QUALITY INDEPENDENT SCIENCE

The GCMRC is established to provide high quality independent science assessments to the AMWG. To accomplish these goals, specific protocols regarding science-planning, competition, peer-review, administration and publication have been established.

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[3]Appendix A contains “resource sheets” which represent a matrix linking stakeholder objectives and information needs to potential monitoring and research statements.

An independent Science Advisory Board will be established to oversee and provide advice regarding scientific planning and methodologies adopted by GCMRC. The selection of this interdisciplinary group of advisors will be based on their standing and accomplishments in the science community.

The GCMRC will solicit extensive involvement of stakeholders and scientists in defining research agendas and methods. However, it will maintain unbiased and objective programs by independently developing needed monitoring and research projects that will be awarded through competitive science procedures.

Quality science programming and unbiased and objective research findings will be ensured through rigorous scientific peer review protocols. All proposals, data, reports, etc., will be reviewed by independent, external anonymous scientists as well as the GCMRC science team.

PROPOSED MONITORING AND SCIENCE PROGRAMS

Monitoring and science programs proposed in the Strategic Plan include the following:

1. Conceptual modeling and synthesis of existing knowledge.
2. Physical resource program.
3. Cultural resource program.
4. Biological resource program.
5. Socioeconomic resource program.
6. Information technology program.
7. Contingency planning.

Each of these areas represent components of the Strategic Plan where important information will be developed to respond to objectives and information needs specified by stakeholders.

Conceptual Modeling and Synthesis of Existing Knowledge

The conceptual modeling and synthesis of existing knowledge represents two parallel thrusts which will be completed in the first two to three years of the Strategic Plan. The first component, will be development of a conceptual model of the Colorado River ecosystem, and definition of interrelationships of various resource attributes that respond to variable operations of Glen Canyon Dam. The second component will be a focused detailed assessment of all past research associated with the riverine corridor's resources before and after Dam construction, as well as other western riverine corridors not yet dammed, and of similar character and structure to the Colorado River mainstem. These syntheses are also addressed in the individual resource program areas.

Development of a conceptual model and completion of "state-of-the-science" syntheses is critical to understanding this riverine ecosystem and associated impacts from differing Dam operations. They will include extensive integrated data assessment and interpretation, as well as the first comprehensive transfer of information to stakeholders regarding the potential impacts of differing Dam operations on ecosystems and associated resources.

The Physical Resources Program

The physical resources program forms the basis for understanding impacts of dam operations on other resources. Water and sediment are the two primary environmental attributes of concern in the physical resources area. Water and sediment are scientifically linked to dam operations, and affect downstream river dynamics, either directly from dam operations, or indirectly from the interaction of differential discharges from dam operations with geomorphology and sediment and water flows entering from tributaries. This basic dynamic of variable flow and sediment regime in turn create the river dynamics that affect resources and their attributes.

Monitoring and research efforts will concentrate on four aspects of these physical resources as follows:

1. Dam discharges and mainstem and tributary streamflow.

2. Sediment flux, and processes, and distribution, and mainstem and eddy interactions.

3. Interrelationship of mainstem water and sediment and tributary inputs and impacts.

4. Changes in Lake Mead Delta.

The Biological Resources Program

Monitoring and research activity for biological resources is intended to develop information about the structure and function of the Colorado River ecosystem, as well as the impacts of differing Dam operations on the ecosystem and associated flora and fauna. The effort will provide the knowledge base required to implement ecosystem management strategies within an adaptive management framework. It is key that relationships between the biotic and abiotic components of the Colorado River Ecosystem be addressed to predict impacts on critical biological resources.

Monitoring and research activities are proposed in several different areas. These include assessments of aquatic food base, native and non-native fish species, wildlife and other riparian invertebrates and vertebrates.

The Strategic Plan contains proposals to evaluate the status and trends of native fish populations in the Colorado River ecosystem and to collect data that can be used to assess the native and non-native fish communities response to Dam operations resulting from “the effects of the Secretary’s actions.” Native fish species of concern are the humpback chub, razorback sucker, flannelmouth sucker, bluehead sucker and speckled dace.

Monitoring of the non-native trout fisheries in the Lees Ferry reach is proposed to concentrate on growth, survivorship, and changes in population structure, including the contribution from natural reproduction over time.

Changes in the three primary riparian zones along the river proposed to be monitored includes: the old high water zone, new high water zone, and near shoreline wetland communities. Proposals to monitor faunal assemblages (including terrestrial invertebrates) will be aligned with sampling of riparian vegetation habitat changes.

It is proposed that avifauna monitoring emphasize the listed Southwestern Willow Flycatcher and general riparian avifauna (e.g., wintering and breeding waterfowl, riparian obligate species, resident non-obligate species and migrant species) in a biogeographic/geomorphic/seasonal context.

As appropriate the biological resources monitoring and research program will consider and address information needs of the Biological Opinion.

The Cultural Resources Program

The cultural resources program will accommodate both ongoing activities of the Programmatic Agreement (PA), and new programs proposed to address needs of the AMWG.

Activities necessary to the PA will be incorporated into the cultural resources program at the request of the agency and Native American tribal members of the AMWG. Monitoring and research information needs and activities from the PA are expected to be a major component of the GCMRC's cultural resource program.

The Strategic Plan incorporates a more comprehensive perspective of cultural resources than those outlined in the PA. This perspective is derived from objectives and information needs specified by agencies, Native American tribes and other stakeholders, relating to cultural resources and their association with other resources in the Colorado River corridor.

The cultural resources program for the GCMRC is comprised of three primary components: a core program of monitoring and research activities as directed by stakeholders in the AMP, a tribal projects component, and a cooperative programming component. Further, the cultural resources program manager is responsible for coordination with other program managers to incorporate Native American concerns within these programs.

The objectives and information needs specified by the stakeholders have been utilized to incorporated into the following general monitoring and research activities proposed in the Strategic Plan.

1. Develop data and monitoring systems to assess impacts.
2. Develop data to assess risk of damage and loss of cultural resources from varying flow regimes.
3. Develop tribal monitoring programs for evaluation of impacts to cultural resources.
4. Develop a predictive model of geomorphic processes that are related to archaeological site erosion.
5. Develop mitigation strategies related to documented site impacts and monitoring assessments.
6. Characterize resource values through scientific study.

The Socio-Economic Resources Program

There are many socio-economic resources associated with the Colorado River corridor including recreation, electric power and water. The objectives of recreation monitoring and research will be to determine whether recreation is enhanced and safety improved when comparing current or proposed dam operations to historical dam operations, and whether wilderness changes in recreational patterns resulting from the dam operations have any effect on the Canyon's downstream recreation resources.

In the Lees Ferry reach, monitoring methods will be established to characterize changes in sport fish recreation (trout) relative to the Secretary's actions regarding dam operations.

Continued monitoring and research is needed to assess changes in recreational and camping beach areas associated with "the effects of the Secretary's actions."

Hydropower supply is an integral part of the economy of the region. Changes in power operations result from changes in annual dam operations which affects power supply and its costs. Power generation monitoring will also be used for estimating water discharge rates and volumes. A Cost Benefit Analysis (CBA) model is proposed to evaluate all associated market and non-market costs and benefits, including intrinsic or existence values of key resources.

The Information Technology Program

Extensive data and information currently exists in the GCMRC relating to resource levels, quality, and relationship to other resources. Potentially equal amounts of data and information exists within museums, universities, state and federal agencies, etc. However, much of this information has not been evaluated to assess the interrelationship of resource attributes and differing flow regimes.

Several areas of focus will be implemented through the information technology program, including the following:

1. Development of protocols for data collection, processing and use.
2. Development of extensive databases across all resources and a database management system.

3. Development of a robust geographic information system to accommodate multiple layers associated with all resources of interest to stakeholders.

4. Development of databases associated with remotely sensed data not yet incorporated in the GCES database system.

5. Stakeholder direct access to selected data and information in the database management system and GIS.

6. Development of outreach programs to transport data and information to stakeholders and train stakeholders in utilization of data and models incorporated in the information technology program.

Contingency Planning

The projected high inflows to Lake Powell in FY97 created several concerns in involved stakeholders, including operating Glen Canyon Dam at high sustained flows (>25,000 cfs), modifying flows to permit research assessments, and possibly having to respond to a spill.

These concerns have now raised critical issues for discussion, including:

- Now that the Adaptive Management Program is in place, what new processes and protocols are needed to ensure the GCPA is appropriately implemented under existing laws, regulation, compacts, etc.?
- How should the GCMRC respond to the AMWG, the BOR, NPS, other agencies, Native American Tribes, etc., when events occur that are not fully predictable?

These events, concerns and issues have resulted in contingency planning by both BOR and GCMRC. The GCMRC did not have contingency plans in place to respond immediately to the implementation of high sustained flows in February, 1997. Further, many stakeholders noted to both the BOR and GCMRC that more effective processes were needed for unplanned events, to assure stakeholder involvement and the implementation of effective monitoring and research programs.

As a result of the above, several activities have been implemented by BOR and GCMRC to assure appropriate process as outlined in the GCPA and GCDEIS, and effective research accomplishment for unplanned events. In FY97, the following contingency plans were initiated or developed:

1. Development of alternative contingency plans by GCMRC for implementation of baseline assessments before and/or after unplanned events.

2. Development of a "White Paper" to initiate discussions on new protocols and procedures to assure appropriate implementation of the GCPA, GCDEIS, and ROD.

3. Development of contingency plans by GCMRC to accommodate research assessments of "spills" or other short-duration high flow unplanned events.

Programming to assure that necessary processes for accommodating all of the above will be in place in FY98.

SCHEDULE AND BUDGET

The strategic plan outlined in this document addresses monitoring and research activities for a five year period: fiscal years 1998 to 2002. Each year, in April, a new fiscal year Annual Plan will be drafted and used to structure and guide implementation of specific elements of the Strategic Plan. It will have prior review by the technical working group (TWG) and the AMWG and approved by the Secretary of Interior. Further, specific planning will occur to address Native American Program requirements and Biological Opinion requirements.

This Strategic Plan is designed to guide specific monitoring and research through three fundamental phases:

1. Development of conceptual ecosystem models, synthesis of existing knowledge, and determination of key attributes associating resource impacts to dam operations.
2. Definition of integrated impact of key attributes within a resource set and across all resources.
3. Development of decision support guidelines and models to assist managers and interested stakeholders to understand resource interactions, impacts of dam operations on resources and procedures for mitigating impacts.

Phase 1 will require fiscal years 1997, 1998, and 1999, for completion. Fiscal years 1998 and 1999 will be utilized to develop conceptual models of the Colorado River ecosystem. Fiscal years 1998 and 1999 will also be used to develop comprehensive synthesis of past research information across all resources.

Phase 2 which will be implemented in fiscal year 1998, is not expected to be completed during the first five year implementation of the Strategic Plan. This relates to the significant lack of knowledge on key driving attributes for many physical, cultural and biological resources. However, significant results will be obtained for some resources, including physical and cultural resources.

Phase 3 of the Strategic Plan will be implemented in fiscal year 2000/2001, primarily for predictive models in the cultural and physical resource areas. However, it is anticipated that development of useful operational algorithms and models in many of the biological resources areas will require most of a second five-year strategic plan. Development of a comprehensive and robust decision support system (dss) is not anticipated until the end of the second five-year strategic plan.

Budget for this five-year Strategic Plan is anticipated at approximately $7 million dollars per year. Of the total $7 million dollar per year annual budget allocation, approximately $5.0 million dollars will be placed into on the ground research programs. Approximately $0.5 million dollars is required by the Upper Colorado Region of BOR to administer the Adaptive Management Program, and approximately $1.5 million dollars is required to operate all of GCMRC's administrative programming.

THE GRAND CANYON MONITORING AND RESEARCH CENTER

LONG-TERM MONITORING AND RESEARCH STRATEGIC PLAN

CHAPTER 1

HISTORY OF MONITORING AND RESEARCH IN THE GRAND CANYON

The U.S. Department of the Interior (USDOI) Grand Canyon Monitoring and Research Center (GCMRC), was established by the Assistant Secretary for Water and Science in 1995. This Long-term Monitoring and Research Strategic Plan (Strategic Plan), is designed to implement, within the GCMRC, new concepts of adaptive management and ecosystem science called for in the Grand Canyon Protection Act (GCPA) and the Glen Canyon Dam Environmental Impact Statement (GCDEIS, 1995). The Strategic Plan is designed to be a guidance document, from which annual monitoring and research plans will be drafted over the period 1998-2002. This first five-year strategic plan, and derived annual monitoring and research plans include extensive synthesis of past monitoring and research, as well as in depth programs for needed future ecosystem monitoring and research. The Strategic Plan presents brief historical documentation of past science, as well as more in depth discussion of planned future strategic monitoring and research programs. An appropriate starting point is discussion of historical science in the Grand Canyon.

SCIENCE IN THE GRAND CANYON

The first formal scientific investigations in the Grand Canyon and associated riverine area were conducted by John Wesley Powell (Powell 1869). Powell's scientific investigations included technical assessments of physical and cultural resources associated with the Grand Canyon Region, including the first ethnographic study of indigenous peoples. Powell's profound accomplishments resulted, in part, in the founding of the U.S. Geological Survey. Since Powell's initial investigation, significant scientific studies have been conducted in the Grand Canyon by many differing individuals, groups, and institutions.

In the first half of this century, economic interests paralleled scientific interest in the canyon. The Colorado River represented a significant opportunity to harness extensive hydroelectric power and provide water storage for growing agriculture and urban development in the Southwest. These interests culminated in the completion of Glen Canyon Dam in 1963, a facility that impounded over 25 million acre feet of water in Lake Powell.

Glen Canyon Dam was heralded as an economic and recreational resource for peoples of the Southwest. It was also criticized as a man-made instrument that destroyed valued Colorado River resources, both upstream and downstream of the Dam. Concerns over potential damage to downstream resources have been persistent since 1963, and relate to both the existence of the dam and operating criteria used for power generation.

Widespread interest in the potential operating impacts of Glen Canyon Dam on river resources resulted in the establishment of the Glen Canyon Environmental Studies (GCES) Program by the Bureau of Reclamation (BOR) in 1982 (NRC 1987). That program operated until October 1996, and accumulated extensive research information on biophysical, cultural, and socio-economic resources. There has also been significant study of canyon resources by organizations and individuals not directly affiliated with the GCES Program. These projects were ongoing before establishment of the GCES program, and they have continued through the duration of that program. Unlike these projects, GCES had unified themes in several resource areas.

The GCES Program general mission was to investigate relationships between Glen Canyon Dam operations and changes in Colorado River resources throughout Grand Canyon (Howard and Dolan 1981, Turner and Karpiscak, 1980; Laursen et al. 1976, Dolan et al. 1974). Although some effects of flow regulation were relatively obvious in 1982, many other cause-and-effect relationships and ecosystem links between Glen Canyon Dam operations and the downstream river environment were poorly understood.

The GCES Program was conducted in two phases: Phase I from 1982-1988 and Phase II from 1990-1996. Phase I studies involved federal and state agency related research, with some studies and summary efforts extending to 1988. The program included descriptive studies of aquatic and terrestrial biology, avifauna, sediment-transport processes, hydrology, and recreational use. The results of Phase I research were presented as a series of single discipline technical reports and publications (USDOI 1988a, 1988b). These studies confirmed that dam operations affected downstream resources. However, 1983 through 1986 were high inflow years and the resulting reservoir spills limited scientific understanding of effects from low fluctuating flows resulting from typical hydropower operations, the primary focus of the original research.

Following their review, the National Research Council (NRC) commented that despite extensive research during Phase I, the GCES single-discipline reports lacked integration (NRC 1987). No conceptual ecosystem model had been developed to guide hypothesis testing, and the resulting understanding of the system was therefore less complete than it could have been had the studies been integrated from the start. For example, information on hydrology and organic material in the water column had not been brought together with information on humpback chub diet, to examine food availability over time and space. To provide deeper insight into the implications of initial research, documentation was prepared to summarize the results and conclusions of Phase I research (USDOI 1988b).

The NRC concluded that the GCES Program had demonstrated that impacts on Grand Canyon resources were related to Glen Canyon Dam operations could be reduced (NRC 1987). In 1988, the DOI concluded that additional technical information was needed before dam operations could be modified in order to minimize impacts on downstream resources. A Phase II program was then launched encompassing a broader base of resources, to respond to external criticism.

Phase II planning studies began in 1988. At the recommendation of the NRC, a senior scientist was appointed to provide direction and oversight for the overall GCES science plan (Patten 1991).

Shortly after Phase II studies began, the DOI mandated an Environmental Impact Statement on the operation of Glen Canyon Dam. The goals and schedule of Phase II studies were then modified and accelerated to support the Environmental Impact Statement process. This (BOR 1995) redirection of Phase II studies eliminated aspects of integration that had originally been planned, in favor of rapid evaluation of areas of special concern for the environmental impact studies (Graf 1990, Webb et al. 1991, Melis and Webb 1993, Melis et al. 1994, McGuinn-Robbins 1995, Melis et al. 1995, Schmidt and Rubin 1995, Stevens et al. 1995, Stevens and Wegner 1995, Webb and Melis 1995, Webb 1996, Webb et al. 1996).

At present, relationships between the geomorphic framework of the Colorado River, including its hydrology, geology and sediment, and its aquatic and riverine habitats and related resources, are only partially understood despite considerable research efforts aimed at understanding the individual components of the river system.

Phase II studies included research on sediment transport (e.g., Schmidt and Graf 1990, Andrews 1991, Cluer 1991, Cluer and Carpenter 1993, Schmidt 1993, Schmidt and Rubin 1995, Wiele, Graf and Smith 1996), organic drift (e.g., Angradi and Kubly 1994, Ayers and McKinney 1995), benthic ecology (e.g., Czarnecki and Blinn 1978, Blinn et al. 1994, Shannon et al. 1994, Stevens et al. 1995), photosynthetically available radiation (e.g., Yard et al. 1993), water quality studies in Lake Powell (e.g., Stanford and Ward 1991, Ayers and McKinney 1996, Vernieu 1996), primary and secondary production in the Colorado River (e.g., Blinn and Cole 1991; Hardwick et al. 1992; Angradi and Kubly 1993; Ayers and McKinney 1995, 1996), diet of humpback chub (e.g., Carothers and Minckley 1981, Kaeding and Zimmerman 1983, Maddux et al. 1987, Kubly 1990), and overview studies (e.g., Carothers and Minckley 1981; Maddux et al. 1987; Angradi et al. 1992; Blinn et al. 1994, 1995; Angradi 1994).

The extensive data base and understanding developed as a result of GCES Phase I and Phase II activities and the GCDEIS (BOR 1995) provides a rich foundation of knowledge upon which the GCMRC program will build. The GCMRC is privileged to have that information as a starting point.

CHAPTER 2

GCMRC PROGRAM JUSTIFICATION AND MISSION

The rich history of research and developed information noted briefly above, primarily by the Bureau of Reclamation GCES Program, the GCDEIS (BOR 1995) and National Park Service, has provided significant assessment of impacts of dam operations on selected resources. Interested parties and agencies who are charged to protect and manage these resources have now realized that effective protection and management will only be attained through an improved understanding of the interacting components of the system, offered via ecosystem assessments using both monitoring and research efforts. Further, these efforts will be greatly enhanced, if they are accomplished within a well structured adaptive management program (BOR 1995).

Stakeholder concern over a need to understand impacts to canyon resources from an ecosystem perspective has resulted in the Adaptive Management Program (AMP) called for in the Grand Canyon Protection Act of 1992 (GCPA) (PL-102-575), and the Glen Canyon Dam Environmental Impact Statement (GCDEIS) (BOR 1995). The Act and GCDEIS direct the Secretary of the Interior to **"establish and implement long-term monitoring programs and activities that will ensure that Glen Canyon Dam is operated in a manner consistent with that of Section 1802"** of the GCPA. "**Long-term monitoring of Glen Canyon Dam shall include any necessary research and studies to determine the effects of the Secretary's**

actions under Section 1804 of the law on the natural, recreational, and cultural resources of Grand Canyon National Park and Glen Canyon National Recreation Area." The monitoring information is necessary to **"protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including but not limited to natural and cultural resources and visitor use**."

The Secretary's actions shall be implemented "**in a manner fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in Arizona v. California and the provisions of the Colorado River Storage Project Act of 1956 and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exploration of the waters of the Colorado River Basin**." Actions of the Secretary will also be consistent with all other federal and state laws relating to resources, federal, tribal state, and local interests.

GRAND CANYON MONITORING AND RESEARCH CENTER MISSION

The EIS for future operation of the Glen Canyon Dam specifies the establishment of the (AMP) for assessment of Glen Canyon Dam operating criteria as defined in the Record of Decision (BOR 1995), (USDOI 1996). The AMP includes development of an Adaptive Management Work Group (AMWG) and the Grand Canyon Monitoring and Research Center (GCMRC) to guide and conduct assessments.

The AMWG includes representatives from federal and state resource management agencies, Native American tribes, and a diverse set of other private and public stakeholders. The AMWG is appointed by the Secretary of Interior as a federal advisory committee to work cooperatively with the GCMRC in implementing the AMP (BOR 1995). In adaptive management, the decision and management process should constantly evolve (Lee 1993) with continuous input of new information from the GCMRC.

The mission of the GCMRC is to develop and implement long-term monitoring and related research and other scientific activities to determine "The effects of the Secretary's actions"[1]//// on the natural, recreational, and cultural resources of Grand Canyon National Park and Glen Canyon National Recreation Area, as well as other information needs specified by the AMWG, utilizing an ecosystem science paradigm. The GCMRC is mandated to inform the AMWG of resource protection, management and use implications of differing operations criteria evaluated.

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[1]/As specified in the 1992 GCPA and reflected in the Record of Decision of the Glen Canyon Dam EIS (USDOI 1996).

CHAPTER 3

SCIENCE PROGRAMMING WITHIN ADAPTIVE MANAGEMENT

INTRODUCTION

Figure 3.1 contains a schematic of the Adaptive Management Program (AMP) and its critical entities, including the Monitoring and Research Center, now designated as the GCMRC. Following are the defined roles for other specified entities in the AMP.

Secretary of the Interior/Assistant Secretary for Water and Science/Designee:

To serve as the Secretary's principal contact for the AMP and as the focal point for issues and decisions associated with the program. Responsibility would include ensuring that the DOI complies with its obligations under the GCPA and GCDEIS. The designee would review, modify, accept or remand the recommendations from the AMWG in making decisions about any changes in dam operation and other management actions.

Adaptive Management Work Group (AMWG):

To provide the framework for AMP policy, goals, direction and priorities. Develop recommendations for modifying operating criteria (and plans) and other resource management actions. Facilitate coordination and input from interested parties. Review and forward the annual report to the Secretary and his designee on current and projected year operations. Review and forward annual budget proposals. Ensure coordination of operating criteria changes in the Annual Operating Plan for Colorado River Reservoirs and other ongoing activities.

Technical Work Group (TWG): To articulate to the GCMRC the science and information needs expressed in the objectives defined by the AMWG, and to assist in recommending science priorities.

Independent Science Review Groups: Independent science advisory boards and review groups will provide independent science assessments of proposed research plans and programs, technical reports and publications and other program accomplishments.

The Adaptive Management Program and processes for determining future operations of Glen Canyon Dam

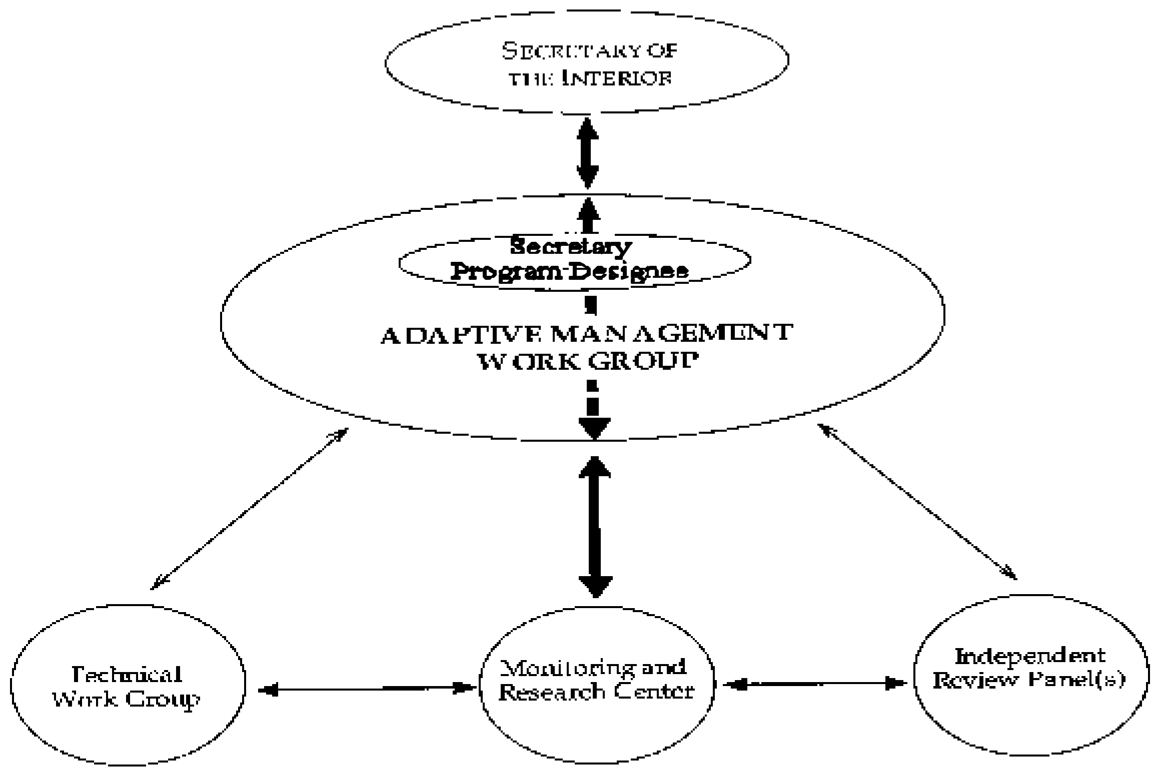

Figure 3.1. Adaptive Management Program Entities.

ADAPTIVE MANAGEMENT

Adaptive management begins with a set of management objectives and involves a feedback loop between the management action and the effect of that action on the system (Figure 3.2 [USFS & BLM, 1994]). It is an iterative process, based on a scientific paradigm that treats management actions as experiments subject to modification, rather than as fixed and final rulings, and uses them to develop an enhanced scientific understanding about whether or not and how the ecosystem responds to specific management actions.

The process begins with the definition of a series of management objectives defined by stakeholders and managers of the system. Once management objectives have been articulated and agreed to, management actions based on current "state-of-the-science" assessments can be taken to achieve these objectives.

An important interim step in this process is to allow for a dialogue between managers, stakeholders, and scientists who are knowledgeable about the system in question. Such a dialogue provides an opportunity for scientists to "reality-test" management objectives. That is, if managers wish to attempt to manage a system for a given outcome that is not feasible, it is important that they understand that at the outset. Experience has demonstrated that such a "scientific reality-testing" of management objectives leads to a better outcomes in the long-run. Bridging the culture between scientists, managers, and stakeholders takes commitment and effort.

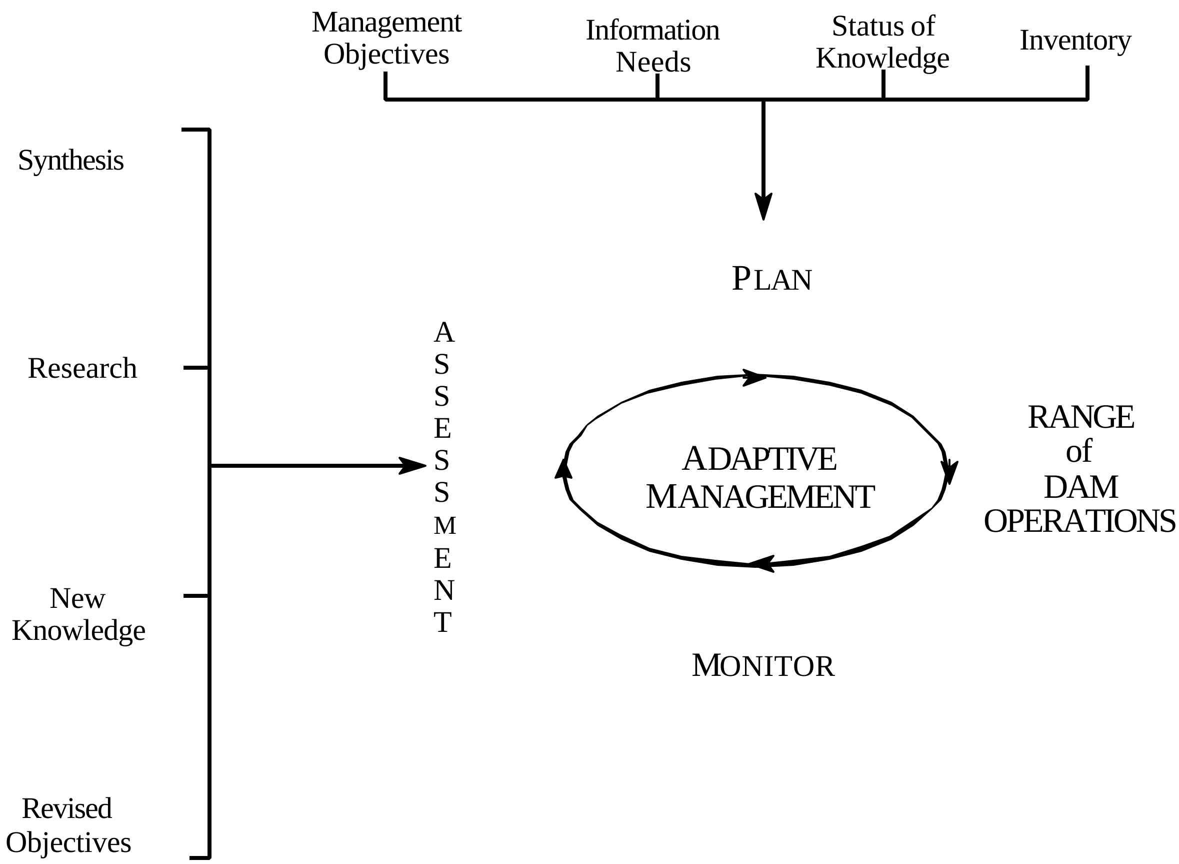

Figure 3.2. The Grand Canyon Monitoring and Research Center's approach to Adaptive Management (modified from USFS and BLM, 1994).

According to Lee (1993), "An adaptive policy is one that is designed from the outset to test clearly formulated hypotheses about the behavior of an ecosystem being changed by human use. In most cases, these hypotheses are predictions about how one or more important species will respond to management actions." An adaptive design permits learning from a policy action, so that future decisions can proceed from a better knowledge base.

Understanding derived from inventory, monitoring, and research efforts are used to predict how the resources of interest will both interact and respond to alternative management actions. The system is monitored to see if it responds to the management actions as predicted. Learning takes place as a result of the monitoring, and the management actions are adjusted in response to new knowledge or insights regarding ecosystem functioning. In most instances, a research program coupled with the monitoring program, is required to discern the nature of the cause and effect relationships indicated by the monitoring program.

Lee (1993) points out that, "Reliable knowledge comes from two procedures: controls and replication. Replication is essential because if knowledge is reliable it can be shown to work more than once; real relationships between cause and effect will show up consistently."

What is unique about an adaptive management approach to decision making is not simply the existence of a feedback loop between the management action and outcome, but rather the use of an explicit monitoring and experimental design that has appropriate controls and statistical power required to test hypotheses: that is to determine if the management action did in fact have the desired (predicted) effect.

ADAPTIVE MANAGEMENT AND ECOSYSTEM MANAGEMENT.

Several steps are required to undertake successful ecosystem management within an adaptive management framework. Ecosystem management requires the ability to see the ecosystem as a whole in some fashion. Baseline ecological information must be gathered and synthesized. Models that integrate the interactions among ecosystem components (e.g., population trends, water quantity and quality and other habitat variables) must be developed. Research must be undertaken to examine cause and effect relationships as a basis for predicting the ecological consequences of alternative management actions and to discern the relative importance of various factors that may impact ecosystem function and provide predictive linkages between species, communities, and the physical setting. Models of these relationships must be developed and tested at appropriate spatial and temporal scales. Models are important tools for organizing data and knowledge and describing the relationships that are believed to represent the important factors affecting the behavior of the system. Models can be used to explore comparison across time or space among biological parameters of interest. These models must be validated and refined in response to the data generated from the monitoring of key ecosystem parameters. Models can also be used to simulate the behavior of the system as a means of testing assumptions about the factors believed to affect the dynamics of the system, to evaluate monitoring data, and to refine hypotheses for testing through experimentation.

THE ROLE OF SCIENCE

The GCMRC conducts independent scientifically rigorous investigations in response to prioritized management objectives and information needs determined by the AMWG. Management and science information will be transmitted constantly (Lee 1993) between the GCMRC and AMWG via the adaptive management process. Science is a powerful mechanism to learn about natural processes for prioritizing outcomes of management actions associated with uncertainty and risk, and for recognizing significant outcomes from unexpected responses. Science will be used to provide critical information and technology to managers and stakeholders in the AMWG, so they can better define management, protection, and use practices appropriate to both dam operations and management of physical, biotic, cultural, and human resources in the canyon.

GCMRC PROGRAMS

The GCMRC will take research and monitoring information from past GCES and other programs and new GCMRC studies, and integrate them into "state-of-the-science" assessments of dam operating criteria. All new GCMRC monitoring and research programs will adopt ecosystem science approaches, which will require integrated resource scientific assessments across space and time. These techniques are well documented in both scientific and management literature as progressive methods for advancing both science and management capabilities, while supporting enhanced protection, management, and use of natural resources.

Long-term monitoring and research activities are used for a variety of purposes including, but not limited to, assessing: 1) natural ecosystem conditions, 2) trends of attributes, 3) definition and refinement of decision criteria, 4) effectiveness of developed decision rules, 5) project impacts,

6) model efficacy, and 7) compliance with standards on resource conditions (MacDonald et al. 1991). Many of these purposes are attributable to the evaluation of the impacts of Glen Canyon Dam operations.

Long-term monitoring

Long-term monitoring is defined here as the repetition of measurements of selected environmental attribute(s) over an extended period of time to determine status or trend in the environmental attribute(s) being monitored. These measurements are made over a period of time and they are different from an inventory. Inventories are a measurement, or a number of measurements, made at a specific point in time. They are often used to establish baseline conditions to which all other measurements are compared, and they are generally the first step in conducting a monitoring effort. The distinguishing attribute of a monitoring effort is the measurement of possible change over time.

Long-term monitoring is conducted to detect and project both expected and unexpected changes in this ecosystem, across time scales as related to the ROD-designated preferred alternative. It will also be utilized to establish current baseline conditions for resources and determine the effects of differing operations criteria on current and pre-dam resource baselines. This portion of the program is expected to be relatively stable, dependent upon consistent methodologies, and modified only after in-depth evaluations. Specific protocols will be developed and reviewed at different intervals for scientific relevance. Maintenance of long-term databases and archives is an essential element of the monitoring program.

Monitoring programs will be developed through cooperative efforts by the TWG and GCMRC and review by the AMWG. Annual monitoring activities will be developed through competitive selection processes that include an open call for proposals and open competition. All monitoring implemented will include independent peer review of proposals, and GCMRC consultation with the AMWG. Criteria for selection of differing proposals will include support of management information needs, scientific capability and merit, and cost effectiveness. Projects and programs will be administered as contracts, cooperative agreements or interagency agreements.

All monitoring data sets will be accessible to outside investigators and interested parties through developed information and technology services, except for selected sensitive data restricted by law, such as endangered species and cultural resource locations or proprietary information such as utility rate structures. All maps, databases, archiving, and retrieval procedures will conform to federal standards.

Research

Research as defined here is the measurement of environmental attribute(s) to test a specific hypothesis or provide descriptive assessments. Research will be used to interpret and explain trends observed from monitoring, to determine cause and effect relationships and resource associations, and to better define interrelationships among physical, biological, and social processes. Research will play an important role in development of integrated methods of monitoring, prediction of key physical and biological processes, definition of resource interactions, and development of ecosystem models. Research programs will be developed through cooperative assessments by the TWG and the GCMRC with review by the AMWG. Research will be founded in the ecosystem science paradigm. However, other appropriate methods may be used to evaluate traditional and cultural values.

The proposed long-term monitoring and research program for the river corridor in Glen and Grand Canyon is not equivalent to a long-term science plan for the entire river corridor ecosystem. It is critical to distinguish this program, whose intent is the monitoring and research of impacts of operations of Glen Canyon Dam on riverine resources between Glen Canyon Dam and the inflow to Lake Mead. This mission meets the objectives of EIS, the 1992 GCPA and resource management agencies and interested stakeholders.

The Centers' mission is constrained by design. For this reason upstream monitoring in Lake Powell, and in tributaries, (i.e. Little Colorado River), is constrained to those probable impacts associated with dam operations. All parties involved realize these to be constraints that inhibit understanding of the entire system. Nevertheless, the ultimate purpose of this program is to monitor resource changes in the riverine corridor and associated reaches that are explicitly related to dam operations.

Information technologies

Information technologies, including information archiving and transfer is a third critical part of GCMRC programming. The program will be directed primarily toward managers and stakeholders, including representatives of the BOR, National Park Service (NPS), Fish and Wildlife Service (FWS), Native American tribes, associated state resource agencies, and a broad cross section of other non-government and non-management entities. The GCMRC views this part of the science program as critical to realizing the full benefit and power of the AMP.

Information archiving will be based on collection of information from monitoring and research projects under prescribed protocols, including, but not limited to, electronic, written, photographic, and video format. New GCMRC information will be added to information previously developed under the GCES Program with metadata collected for each research and monitoring element. Selected information will be archived and available only to specific parties. For example, restricted data access protocols are being developed regarding proprietary information such as locations of cultural resources and endangered species.

Information transfer programs will utilize a broad array of methods to bring monitoring and science information to users. This will include computer access, Internet connections, computer tapes and disks, audio and video tapes, reports, publications, symposia, workshops, briefings, etc.

REQUEST FOR PROPOSALS (RFPS) AND PEER REVIEW

As recommended by the NRC (1996), GCMRC will utilize a competitive proposal solicitation process open to government employees, public-section contractors, and universities through an open Request for Proposals (RFPs). Monitoring and research projects will be selected on the basis of their support of scientific capability and merit, submission timeliness on previous work (as evaluated through an independent, objective and unbiased peer review process), management objectives and information needs, demonstrated capabilities of proposers, and cost effectiveness. Following the selection of proposals, appropriate procurement mechanisms (i.e., grants, contracts, cooperative agreements) will be utilized for supporting selected projects. Most cultural resources programs, falling under the Secretary's trust responsibilities, will be subjected to the same review protocol with a decision point only under after required revision.

GCMRC's commitment to ensuring the high quality of the scientific information produced by its programs highlights the importance of peer review at all levels of GCMRC scientific activities. GCMRC is committed to the use of scientific peer review and is drafting a set of peer review guidelines to describe the level of review received by all GCMRC proposals, programs, publications, and other products; and clearly convey the unambiguous standard of scientific objectivity and credibility followed by GCMRC.

These guidelines for scientific peer review will ensure that GCMRC matches the level of peer review to the nature of the proposal, program, publication or other product being reviewed, and describe the selection of qualified scientific peers, independence of the review process, and the inclusion of external (i.e., outside GCMRC) reviewers in the scientific peer review process.

In general, following approval by the AMWG of the long-term monitoring and research strategic plan, an annual monitoring and research program will be completed and approved each year in April. After approval of the annual monitoring and research plan, RFPs will be issued. Proposals will be screened by the program managers for their responsiveness to the RFP and all qualified proposals will undergo an independent and objective scientific peer review. Awards will be made on the basis of the results of peer review, along with the program manager's evaluation of project relevance, and technical contracting requirements.

GCMRC's peer review guidelines will be consistent with the "U.S. Department of the Interior Guidelines for Scientific Peer Review of Research" issued by the Secretary of Interior. These include:

- Objectivity and independence of reviews.
- Reviews conducted by true scientific peers, as judged by demonstrable scientific achievements.
- Independence of peer reviewers.
- Provision of constructive feedback to the investigator.
- Anonymity for peer reviewers, unless waived.
- Periodic evaluation of the effectiveness of the GCMRC peer review process.

GCMRC'S SCIENCE ADVISORY BOARD (SAB)

To ensure that the long-term monitoring and research activities initiated by GCMRC are unbiased and objective, scientifically sound, and focused on the most important issues, an independent Scientific Advisory Board (SAB) will be established to advise GCMRC on the coordination and planning of its monitoring and research programs, and to review the results of GCMRC's monitoring and research programs. The SAB is synonymous with the Independent Science Review Group (ISRG) specified in the GCDEIS (BOR 1995). The SAB will be an advisory and not a decision-making body, but both the GCMRC and the AMWG should be prepared to explain why it has accepted or rejected advice provided by the SAB.

The SAB will be an interdisciplinary board, composed of scientists who are qualified, based on their record of scientific achievement, in a range of disciplines related to the work of GCMRC. Scientists will be selected for their expertise and not as representatives of a particular agency, organization, or other stakeholder group.

Members will be selected for a three-year term, renewable for one consecutive three-year term. The initial members of the SAB will be selected for staggered one, two, and three year terms, to ensure that their is continuity in membership on the SAB and that all of the members do not turn over at one time.

The SAB will be expected to meet at least twice each year and to provide ongoing consultations to any of the GCMRC's program managers. All meetings of the SAB and any reports produced by the SAB will be open and available to the public.

Consistent with government regulations, where appropriate, SAB members will be reimbursed for their time spent reviewing and commenting on GCMRC materials, activities, and programs. SAB members will be prohibited from competing for GCMRC long-term monitoring and research awards while they serve on the SAB and for two-years following completion of their term of service.

ADMINISTRATION

Administration of GCMRC programs will be accomplished by a staff of 8-10 permanent full-time science and technical specialists and 8-10 term-appointed specialists. The Chief and three Program Managers representing physical, biological, and cultural resource disciplines will comprise the primary program management positions in the Center, along with an Information/Technology Program Director. The Cultural Resource Program Manager will direct all Native American program coordination across resources. The Center Chief will direct socio-economic monitoring and science programs in addition to overall program administration.

The GCMRC Chief's primary responsibility will be to provide adaptive management and ecosystem science leadership for program planning and design, implementation, and interpretation. The Chief also provides external liaison to the office of the Secretary, other agencies, Native American tribes, non-governmental organizations and the public. Program Managers will exercise primary responsibility, with the Chief, for science interpretation in their resource areas. The Biological Resources Program Manager also serves as the Associate Center Chief in providing overall program leadership and serving as the Acting Chief in his absence.

The program managers will be supported by research analysts and a senior research/field scientist. In addition, GCMRC will retain in-house surveying capability, needed to ensure consistency and continuity with respect to the accuracy of the physical location of sites and resources to be monitored. Finally, GCMRC will also provide logistical planning and support to scientists proposing work in response to program solicitations. As appropriate the above duties and responsibilities will be carried out by permanent full-time or term employees.

CHAPTER 4

STRATEGIC RESEARCH PLANNING UNDER REVISED PARADIGM AND INSTITUTIONAL CONSTRAINTS

The Grand Canyon is a unique, complex and dynamic environment. It is also a highly regulated system, in terms of river flows and use. Its uniqueness demands careful stewardship. In the face of evolving scientific understanding about the Grand Canyon's riverine ecosystem, it is not yet possible to identify only a few attributes that characterize the entire system. In light of this uncertainty, it would be irresponsible to restrict science within the river corridor ecosystem to a very small number of attributes and assume that all other attributes are related to those measured.

This proposed program is designed to evaluate resource changes and impacts associated with differing dam operating criteria, and it must accomplish assessments utilizing an ecosystem science paradigm, and in a cooperative adaptive management program with all concerned stakeholders. The program attempts to strike a balance between the extremes of: 1) very restricted monitoring which recognizes the impacts of scientific study on the essence of what the Grand Canyon means to most humans, and 2) full measurement of all ecosystem attributes predicated on a belief that an unmeasured parameter might be critical at a later time.

CRITICAL ATTRIBUTES

The monitoring and research programs emphasize measurement of attributes deemed critical for evaluating resource effects of alternative operations of Glen Canyon Dam. The prediction and significance of potential attribute response to dam operations is discussed in four general program areas, i.e., physical, biological, socio-economic, and cultural. Under the long-term monitoring program, responses of these critical attributes will be used in adaptive management decisions. Critical attributes developed in the Glen Canyon Dam EIS process, and utilized in this Strategic Plan follow:

1. Quantity and quality of water from Lake Powell and in the Canyon.
    a. annual stream flows in mainstem and key tributaries
    b. discharge rates and lake volume and spill frequency
    c. chemical, physical and biological characteristics of water in Lake Powell and the Colorado River from Glen Canyon Dam to Lake Mead.
2. Sediment supply and transport.
    a. stored riverbed sand
    b. mainstem and eddy complex interactions
    c. elevated sandbar erosion
    d. dynamics of debris fans and rapids
    e. tributary stream dynamics and sediment flux; backwaters
    f. nutrient dynamics

3. Fish.

   a. aquatic food base

   b. reproduction, recruitment and growth of native fishes

   c. reproduction, recruitment and growth of non-native warm water and cool water fishes including trout

   d. habitat condition and availability

   e. competition parasitism and predator-prey interactions

4. Vegetation.

   a. area and species composition of riparian plants

   b. area and species composition of emergent marsh plants

5. Wildlife and wildlife habitat.

   a. area and species composition of riparian habitat for associated vertebrates and invertebrates

   b. aquatic food base for terrestrial vertebrates

6. Endangered and other special status species, their habitat and food base.

   a. humpback chub

   b. razorback sucker

   c. bald eagle

   d. peregrine falcon

   e. southwestern willow flycatcher

f. belted kingfisher

g. Kanab ambersnail

h. other federal and state species of concern

7. Cultural resources.

a. archaeological sites directly, indirectly, or potentially affected such as those on high water terraces

b. Native American traditional cultural properties directly, indirectly, or potentially affected

8. Recreation.

a. fishing trips and angler safety

b. day rafting trips attributes and access

c. white-water rafting trip attributes, camping beaches, safety, and wilderness values

d. navigability

e. net economic value and regional economics

9. Hydropower production to network and customers at lowest costs.

a. changes in power operations

b. power marketing benefits lost or gained

10. Non-use valuation.

a. values placed on Glen and Grand Canyon riverine system by the public

This program also adopts a conservative approach of measuring attributes that reasonably might be affected by dam operations, and for which no surrogate attributes exist. However, this program does not propose monitoring or research of those attributes clearly unrelated to "... the effect of the Secretary's actions," or those which are adequately represented by other parameters. It also emphasizes use of data collected in the Grand Canyon that are not field intensive. Wherever possible, monitoring will be conducted using non-invasive means.

The program is designed to respond to short- and long-term management objectives and information needs of resource management agencies and stakeholders. Acceptance of changing conditions of each of the above attributes as it responds to dam operations is contingent upon these management objectives. A change in an attribute, determined through the long-term monitoring program, may represent a deviation from an acceptable condition (determined by management agencies and interests) that would trigger consideration of changes in dam operations. The long-term monitoring program would use methodologies that offer appropriate information about the response of the critical attributes to enable the AMWG to evaluate these changes in light of the overall management objectives for the physical, biological, cultural, recreational, and socio-economic resources of the Grand Canyon ecosystem.

THE GEOGRAPHICAL SCOPE OF MONITORING AND RESEARCH PROGRAMS

The area to be monitored is primarily the Colorado River corridor between Glen Canyon Dam and Lake Mead reservoir (Figure 4.1). This area is about 270-280 river miles long, as the headwaters of Lake Mead vary with reservoir elevation. Because the Lake Mead shoreline ecosystem is greatly affected by the reservoir operations and the existence of Hoover Dam, the Grand Canyon monitoring and research program ends at approximately Separation Canyon (RM 280), the generally accepted head of Lake Mead. The program in following the GCPA includes the riverine corridor in the Grand Canyon National Park ending at river mile 293. However, the effects of fluctuations in Lake Mead and the influence of changes in the Colorado River below Separation Rapids resulting from dam operations might be considered as extensions of the geographical scope of the long-term monitoring program.

Despite the linkages that exist between the Grand Canyon and the upstream basin, the appropriate upstream limit for Grand Canyon monitoring and research on the effects of dam operations, is the forebay of Lake Powell. Because of the critical role of reservoir-scale geochemical processes in determining the quality of water at the intake sites, a separate long-term monitoring program in Lake Powell might be evaluated in the future as part of this program. However, a Lake Powell long-term monitoring program is not being considered as part of the GCMRC long-term monitoring and research program at this time. A one-year assessment of potential impacts of past operating criteria on Lake Powell water quality is

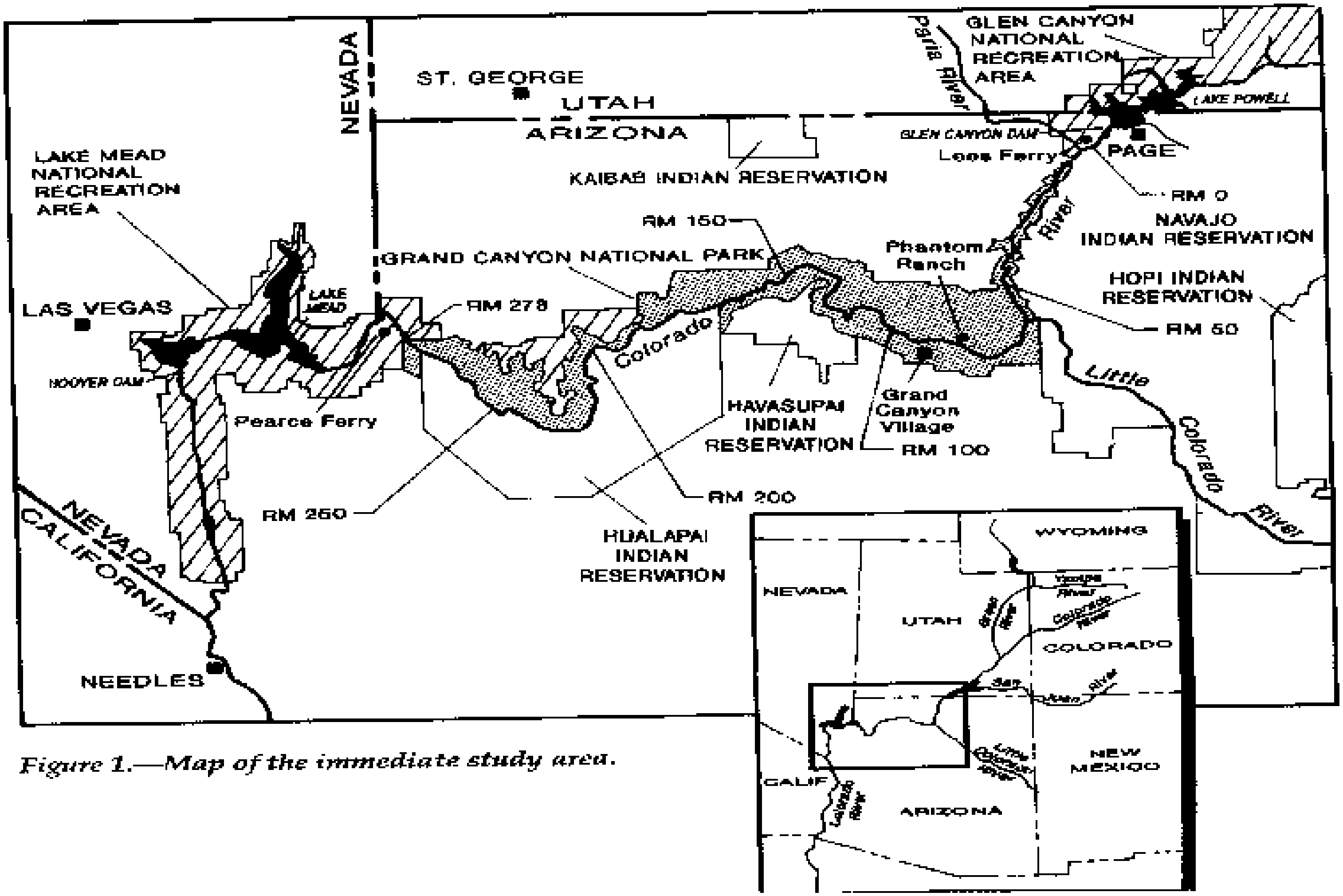

Figure 1.—Map of the immediate study area.

Figure 4.1. Map of the GCMRC Study Area.

approved for fiscal year 1997. Along this same line, ongoing studies in and along the shoreline of Lake Mead within normal pool fluctuation are also not considered part of the GCMRC program at this time.

The lateral extent of the monitoring effort is defined by the extent of processes and conditions influenced by dam discharges and river flows associated with operating criteria in the ROD. The relevant lateral study zone area is the maximum regulated discharge and the inundated area for mean annual pre-dam peak flow of 90,000 cfs. However, the old high-water zone vegetation community begins at about this elevation and extends to higher levels. Arroyo head cutting caused by current low flow operations may extend above this level. Thus, it is prudent in some areas of the Canyon to include elevations above the stage associated with a discharge of 100,000 cfs.

Thirteen reaches, varying in length between 2 and 12 miles were established by GCES as Geographic Information System (GIS)-reaches (Figure 4.2), and detailed topographic data at a scale of 1:2400 are available for these reaches. These sites were selected because they represent reaches of the Colorado River in which there were ongoing studies or potentially important ecological conditions. Although the scientific basis for their selection did include considerations of the long-term representativeness, at some point data on all reaches will eventually be put into the GIS. As a consequence, additional sites may be selected as programs proceed, to adequately represent geomorphically distinctive reaches.

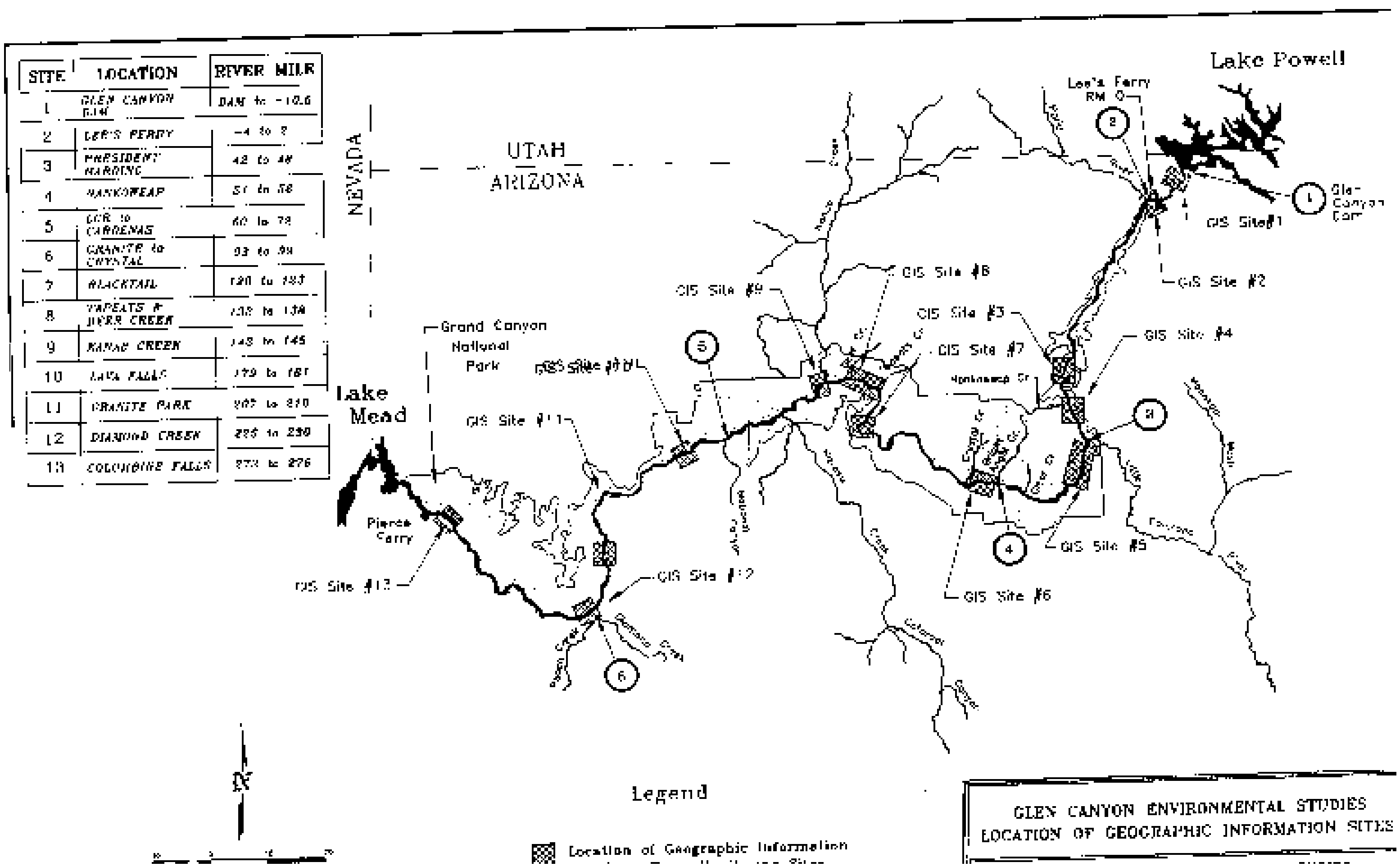

Figure 4.2. Map of the GIS-reaches established by GCES (March, 1992)

CHAPTER 5

DEFINING STAKEHOLDER OBJECTIVES AND INFORMATION NEEDS

Stakeholder, or management objectives define measurable standards which serve as targets to be achieved within the AMP. These targets serve as the basis for identification of necessary information to be developed through the long-term monitoring and research program of the GCMRC.

Stakeholders objectives were organized within the various resource areas that had been identified during the EIS process. These broad areas were addressed and discussed within the framework of the adaptive management process to formulate stakeholder objectives and the resultant information needs. Figure 5.1 indicates the resource areas where objectives are developed as part of the EIS and long-term monitoring and research planning process.

STAKEHOLDER OBJECTIVES

Stakeholder objectives were developed in the Spring of 1996, by a working group of stakeholders at a series of workshops organized by the Upper Colorado Regional Office of the BOR. During these workshops, the process of clarifying and consolidating the management objectives to clearly identify the management needs to the researchers and the GCMRC was begun. Objective statements were obtained from the group and condensed

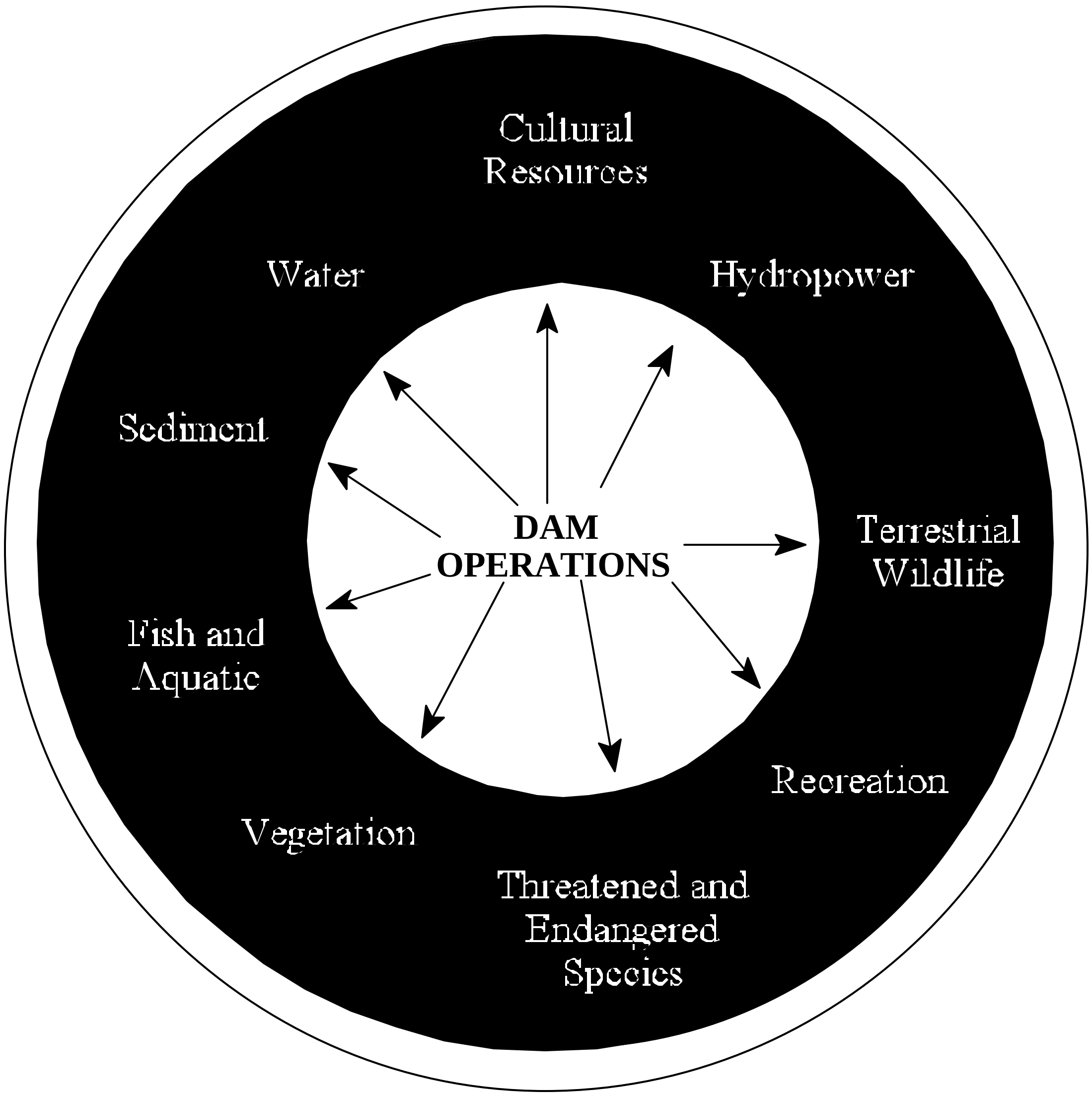

Figure 5.1. Issue Areas Proposed by the Transition Work Group for monitoring and research.

into specific objectives relative to each resource. The stakeholder objectives are included on the resource sheets in Appendix A and organized by resource. Appendix B includes the objective statements of several agency stakeholders. These objectives can be identified within the content of the various resource sheets (Appendix A).

INFORMATION NEEDS

A series of meetings were held between May and September 1996 to gain input on the information needs (research, monitoring, development) of stakeholders who are involved with protection, management, and use of resources in the riverine environment of the Grand Canyon. Interactive meetings were held with a subgroup of representatives from a larger cross section of stakeholders included in a Transition Working Group. The Transition Working Group was organized by the BOR as an interim body of stakeholders with which agencies could work until an AMWG was appointed.

The development of the information needs assessment was facilitated by the GCMRC based on objectives outlined in the GCDEIS and management objectives identified during BOR coordinated stakeholder meetings. The information needs assessment consisted of drafting appropriate broad data needs based on the objectives, and subject to constraints on scope of monitoring and research within the GCMRC.

The set of information needs identified by resource area and management objective are listed on the resource sheets in Appendix A. These expressed needs will become the primary basis for developing short-and long-term monitoring, research, and information transfer programs for the GCMRC.

CHAPTER 6

MONITORING AND SCIENCE PROGRAMS

This segment of the plan addresses six primary areas of the Strategic Plan:

1. Synthesis of Existing Knowledge
2. Physical Resource Program
3. Cultural Resource Program
4. Biological Resource Program
5. Socio-Economic Resource Program
6. Information Technology Program

SYNTHESIS OF EXISTING KNOWLEDGE

A long standing concern with scientific studies is that a comprehensive evaluation of existing knowledge is needed for appropriate development of a long-term monitoring and research program. Therefore, in the first two years of implementation, we intend to undertake an extensive synthesis of existing knowledge. A primary outcome of the synthesis will be to use the increased knowledge to revise the Strategic Plan in year three. During the two year period, the GCMRC will also continue critical monitoring programs developed during the transition from the GCES to the GCMRC programs.

The synthesis will be developed to pursue two key objectives:

1. To define a conceptual systems model of the riverine ecosystem processes, related critical resource interactions, and their specific associations to stakeholder objectives and information needs.
2. To define driving attributes (effectors) for critical resources of interest, and where possible attributes that act as linkages or effectors across or among resources.

The second objective will be addressed through two separate syntheses of existing knowledge.

1. Determine, where possible, baseline conditions for critical Colorado River resources prior to dam construction.,
2. Define resource attribute changes in the Colorado mainstream since dam construction and under differing operating criteria. Contrast with changes in resources in other riverine systems which have not been damned.

Conceptual Systems Model:

Following the articulation of management objectives, a conceptual systems model of the Colorado River ecosystem will be developed, based on existing knowledge, and concurrent synthesis of new knowledge. This systems model will focus on the specific goals articulated by the AMWG, managers and other stakeholders. Following the development and validation of the conceptual model, parameters to be monitored will be revised based on the known or suspected cause and effect relationships that are identified through the development of the conceptual systems model.

The conceptual systems model and long-term monitoring program must also be designed in recognition of the spatial and temporal characteristics of the Colorado River ecosystem in Glen and Grand Canyons. Given the range of spatial and temporal scales at which Colorado River resources function, this may mean that monitoring activities may actually occur only within representative areas of the larger area. The selection of such representative areas will depend upon the process or parameter to be monitored, and the sensitivity or fragility of the resource or habitat.

Similarly, the conceptual system model and associated long -term monitoring programs need to be designed to provide information, over the long-run, on the responses of the Colorado River ecosystem in Glen and Grand Canyons to the long-term operations of Glen Canyon Dam. This will probably require the long-term monitoring program to continue through the life of the dam. The intensity of the monitoring program might change over time, depending on results of periodic reviews of the program. However, the type, frequency and location of measurements still should follow from the goals of the monitoring program as they relate to specified stakeholder objectives and the current knowledge base. Davis et al. (1994, Figure 6.1) has proposed a step down approach for the development of a long-term monitoring and research program that incorporates a conceptual system model.

To reiterate, long-term monitoring should be designed to provide regular feedback for adaptive management which permits mid-course adjustment of Glen Canyon dam operations

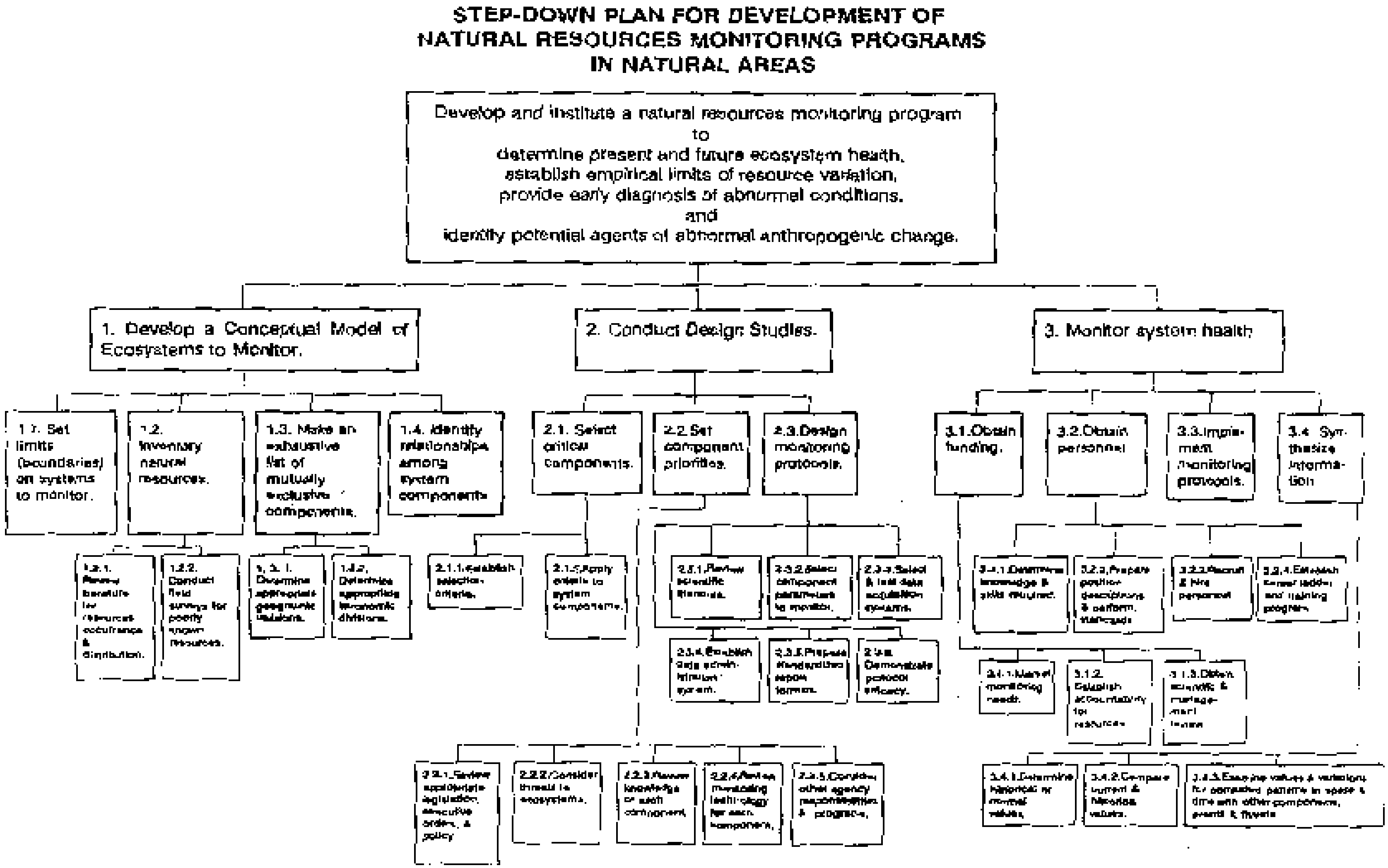

Figure 6.1. Step down Approach to the Development of a Long-term Monitoring and Research Program (Davis, 1994).

to ensure achievement of the goals of the Record of Decision (1996) and the management objectives articulated by the stakeholders.

Experience with the development of long-term monitoring and research programs in an adaptive management framework suggest that it takes at least two years to develop a sound long-term monitoring program (Noon 1996). Critical to the development of a sound long-term monitoring and research program is the development, during the first year of the program, of conceptual and strategic models of the system being studied. The completion of a conceptual model should provide the basis for the development of a sound long-term monitoring and research plan.

Objectives for the conceptual model exercise are threefold.

1. To specify the general system model for the Grand Canyon ecosystem with definition of critical resources, attributes, and attribute linkages.
2. To contribute to definition of information voids, and research and monitoring needs.
3. To function as an education process for scientists and stakeholders in understanding critical science and management issues.

Good simulation models are elegant representations of the ecosystem being studied. That is they are simplifications which contain only the level of complexity needed to describe the behavior being modeled. As such, simulation models are often incomplete representations of the ecosystem under study and their strength--the ability to organize complicated relationships into an understandable framework of study--are also their weaknesses. That is, predictions resulting from ecosystem simulation models will often, be incomplete and therefore require validation through monitoring, experimentation and testing. Models and their associated data bases have been important tools for use by scientists and managers dealing with complex natural systems (Meadows et al. 1982, Fight et al. 1986). In addition, the process of building a simulation model of an ecosystem provides an opportunity to test assumptions and to develop a shared view among scientists and managers of what is being managed and what the management objectives are.

The development of a computer driven conceptual model of the Grand Canyon ecosystem is important because it provides a general framework for understanding how the system works, requires organization of many scattered pieces of information, and imposes a rigorous framework on one's thinking. Computer models are precise and consistent require assumptions and relationships to be written out explicitly so they can be criticized and understood by everyone, can contain many variables and keep track of them simultaneously, can be changed and tested quickly, and can provide a platform for thought and simulated experiments (Meadows et al. 1982, Fight et al. 1986).

Synthesis of Past Knowledge

Development of an effective synthesis of past knowledge will be accommodated through two steps as noted above. Both steps will be developed simultaneously.

One of the interesting quandaries in natural resource science endeavors, especially those that attempt to evaluate impacts of management action over time, is the difficulty of defining what would have occurred to resources in a system had there been no management action. The task is made more difficult when the western riverine ecosystem under study has been significantly altered from its original character.

Many ecosystems are extremely dynamic, and are subject across time and space to natural perturbations that in and of themselves can evoke more significant impact and change to resources in the system than human directed activities over the same period. Nonetheless, when attempting to measure anthropogenic impacts on a natural system through time, such as a large desert river, there is a need to contrast these measured changes to changes in similar riverine systems where there are no man imposed activities. Contrasting these two systems will often permit the scientists to more directly evaluate the natural resource impacts of human induced activities such as a dam and its operation. The more natural system then becomes the control. Contrasting resource changes in these two systems embodies the basic underlying assumption that determined resource departures are in fact due to human induced activities. The assumption is, of course, weakened by the fact that natural perturbations in the control system over time could be significantly different than the managed system, and in fact could overshadow changes due to human induced activities in the managed system.

The scientific challenges faced in evaluating impacts of Glen Canyon Dan operating criteria on downstream riverine resources is much more complex than the above example, if we are considering comparative analyses to other, more natural, western rivers, (i.e., not regulated by a dam). Contrasting resource change due purportedly to dam operations on the Colorado River mainstem against resource changes in a southwestern riverine ecosystem in a more natural state, is obviously confounded by changes due to the dam itself. That is, placement of the dam structure may have so altered riverine ecosystems that any resource changes due to modified dam operations are impossible to determine. This is due in major part to radical changes in hydrology, sediment loads, and temperature regimes in the river, all due to the existence of the dam.

The above observation does not mean that attempting to establish some evidence of original baseline conditions in the Colorado River by observing conditions in somewhat similar rivers without dams is not warranted. Determining pre-dam baseline conditions for the Colorado River mainstem resources and a similar, more natural riverine ecosystem, and contrasting changes in these systems over time is important to this science investigation. For example, even though scientists agree that current population variation in humpback chubs is at least partially caused by existence of the dam and/or dam operations, that does not mean that removal of the dam would in fact restore these populations.. Populations in other, more natural, riverine settings in the western United States also vary and some appear to be in decline. That is, other resource attributes such as interaction with non-native fish, change in climatic variables or water chemistry resulting from agricultural uses upstream may be contributing factors.

There has been insufficient synthesis of knowledge on both the Colorado riverine ecosystem and other western riverine ecosystems to appropriately establish baseline conditions on the natural range of variation in attributes to which we can compare and contrast resource changes over time due to human activities. Although there is high probability that one could not compare any observed changes statistically, such synthesis could be fruitful to the science effort at hand. In fact, descriptive assessments of these type of synthesis may offer considerable insight into changes wrought by dam placement and operating scenarios.

The third objective of the synthesis is to define the most prominent effectors of resources of concern to stakeholders. Definition of these effectors and their probable impact on the resources of concern is required in the context of dam operations under operating criteria specified in the ROD. Understanding effectors from a perspective of the entire ecosystem is critical. Should an effector be found to be prominent, and changes in that effector are potentially positive to a particular resource of concern, it is necessary to know if that change would affect and impact other resources in a negative manner. A critical need from this analysis is to define effectors that are the primary contributor to changes in the resources of concern or to linkages among resources. It is important to determine if these effectors have varied significantly over time, and if the variance in these effectors today are far outside the ranges observed over time, in both pre-dam and post-dam periods.

The primary intent of the synthesis program is to form a basis for guiding more effective monitoring, and prescribing appropriate research questions to specify more explicit relationships among attributes that are effectors both within and among resources. This knowledge is important to making critical adjustments in the following physical, cultural and biological resource science programs in years three through five.

THE PHYSICAL RESOURCES PROGRAM

The physical resource program forms the basis for understanding impacts of dam operations on other resources. Two resources, water and sediment, are scientifically linked to dam operations, and affect downstream river dynamics, either directly from dam operations, or indirectly from the interaction of differential discharges from dam operations with channel geomorphology and sediment and water flows entering from tributaries. This basic dynamic of variable flow and sediment regimes in turn create the river dynamics that affect resources and their attributes.

Variation in some physical resources seem subtle, so minor in fact that little if any variable response would be expected within or among other related system resource attributes. Water temperature is an example: it is maintained in the 47-50EF range by hypolimnetic release from about 250 feet below the surface of Lake Powell. Yet, minor changes in water temperatures downstream can result in significant changes in riverine biota.

Information Needs

Two areas of stakeholder objectives are addressed in the physical resources program: water and sediment. Specific objectives addressed are listed in Appendix A.

A broad array of information needs were specified by stakeholders (Appendix A). The following synopsis of information needs developed characterizes the breadth of stakeholders' concerns for water and sediment resources.

<u>Water</u>

- Monitor changes in the physical and chemical characteristics over time.

- Monitor concentrations of chemical constituents with established EPA/state and tribal standards.
- Measure water composition and temperature and their changes over time.

Sediment

- Characterize sand-bar, backwaters, and return channel target structures.
- Define target backwater ecosystems and associated flow regimes.
- Define character and structure of all beaches and backwaters in system after 1996 test flows.
- Define historical and current (character and structure) levels of river stored sediment in system and associated flow regimes.
- Determine relationships between geomorphological processes and cultural resources.
- Determine baseline conditions.

Within the Colorado mainstem study area, from Glen Canyon Dam to the Lake Mead Delta there are four aspects of water and sediment resources where monitoring and research efforts are important.

1. Dam discharges and stream flows.
2. Dynamics of mainstem and eddy flow and sediment interactions.
3. Tributary inputs and impacts.
4. Changes to Lake Mead Delta.

Dam Discharges

Dam discharges and stream flows create the physical conditions that control many downstream ecosystem processes and components, including: sediment dynamics, habitat development, habitat use, fish recruitment, and fish population dynamics. The objectives for monitoring the Glen Canyon Dam releases and flows are to determine how closely dam discharge follows the prescribed operations of the dam and the extent of the variability in discharge and associated downstream flow variability. These flows which also include discharges or spills above dam hydropower operations, should be monitored at: 1)the Lake Powell forebay, 2) the dam, based on power production, and 3) the U.S.G.S. gauge below the dam. Flows to be monitored include, hourly water discharge (both flow rate and volume) and ramping rates (changes in discharge over the hour). From the above data, synthesis information on maximum and minimum daily discharges and daily fluctuations, and frequency and volume of spills, can be determined and placed in a perspective of average conditions and variance.

The above monitored data streams have been enhanced by ongoing water quality measurements above and below the dam, including significant breadth in physical, chemical, and biological attributes. A critical element of this program area will be development of a synthesis of all historical water quality data and science as it relates to changing dam operations and to changes in other downstream resource attributes.

Continued monitoring and research of water quality attributes in the river and their relationships to dam operations are a critical part of the long term program. Changes in water quality attributes in Lake Powell, and their relationship to dam operations are the subject of intensive assessments in FY 1997. Continued water quality programs in Lake Powell will need to be justified on related impacts due to dam operations.

Physical attributes evaluated in the river environment include temperature, sediment load, conductivity and inorganic compounds; chemical attributes include salts, trace elements, phosphorus and nitrogen; and biological attributes include aquatic biota assessments. Assessment of all these attributes will continue in the Strategic Plan.

Definition of linkages and integration among attributes of physical and biological resources in the Glen Canyon reach of the river is needed to ascertain relationship of flows to primary productivity and the cold water trout fishery. The non-native trout fishery has become an important social and economic resource to diverse publics and it is responsive to changes in primary productivity which in turn is affected by variable flows under differing dam operations.

The 1996 beach habitat experimental flows appeared effective in enhancing primary productivity, but also may have contributed to changes in the standing crop of biomass. A critical research need is development of a model of integrated physical and biotic attribute relationships for the Glen Canyon riverine corridor.

Water and Sediment Transport.

The transport of water and sediment through the Canyon are interconnected (e.g., sediment transport curves of varying quality). Discharge rates and changes in river stage influence the amount of sediment transported and stored in the system. Alluvial sediment is a primary substrate for many riverine biological processes, cultural resources, as well as camping beaches. The objectives for monitoring changes in water and sediment transport are to determine whether the flux of water and sediment through the Canyon is at the level predicted by the EIS for the prescribed operating criteria and whether the flux varies as expected within different reaches of the Canyon. Measurement objectives are: 1) continuously measure the flux of water through Grand Canyon; 2) periodically estimate flux of sediment through the Canyon; and 3) estimate the differences in flux in different reaches. Measurements of flux not only permits comparison of measured differences in fluxes which can be compared with measured storage changes, but the fluxes themselves may be critical determinants of some biological processes (e.g. nutrient dynamics).

A water flow and sediment routing model is being developed by the U.S. Geological Survey, however, it is not yet time to rely solely on this model to estimate fluxes. Some field measurements are still needed to provide appropriate data for model validation in differing reaches.

Traditional gauging stations continue to be relied on in the Canyon, and will remain until improved technology and protocols are developed. Gauging stations do not exist at the end points of each geomorphologically distinct reach in Grand Canyon, using the classification and research of Schmidt and Graf (1990). The emphasis of long-term monitoring will be on maximizing the analysis of data collected at existing gauges, using models to integrate variations in intervening reaches.

River managers have expressed concern about impacts of dam operations on upstream reaches of the Grand Canyon, and these reaches have been shown to have the greatest potential for sediment storage deficit. It is therefore important that gauging stations on the Colorado River at

Lees Ferry, above the Little Colorado River, and upstream from Bright Angel Creek be maintained as sediment measurement stations as well as discharge stations. It is also critical to measure outflow from the system and maintain existing gauging stations, such as the station above Diamond Creek. It is less critical to evaluate flux differences between miles 87-225, and the recent removed gauge above National Canyon is considered the least important gauge in Grand Canyon, although it has been useful for bed movement studies and sediment transport modeling.

If one gauge were to be added in the Grand Canyon, it should be located upstream from Nankoweap Creek (perhaps upstream from Buck Farm Canyon), so that fluxes could be measured through the distinctly different reaches of upper and lower Marble Canyon. These are reaches in which impacts from upramping waves are greatly attenuated. The addition of a new gauge in the Grand Canyon represents a significant increase in the impact of scientific activities on the Canyon. A key task of GCMRC will be to explore alternative strategies to installation of permanent cableways for purposes of water and sediment gauging. Should alternatives be determined, especially cost effective alternatives affording lower impacts to Canyon resources, current gauging technology may be replaced.

The ongoing water and sediment modeling effort is primarily a research effort and represents a long-term alternative to continued widespread gauging presence in the Grand Canyon. Such modeling should also create the capability for calculation of flux differences in many of the short reaches of the Grand Canyon which have limited study. Other water and sediment modeling efforts would be considered part of long-term research, such as deposits in and erosion of side channel debris, changes in existing rapids, formation and degradation of beaches, and arroya down-cutting in upper terraces.

Measurements of sediment fluxes will be the basis for computing annual reach-scale sediment budgets of the Grand Canyon. The sediment budget approach to river management has been endorsed by geomorphology and sediment researchers (GCES Fort Collins, 1992). Because there are insufficient gauges to compute sediment budgets for all geomorphic reaches of Grand Canyon, such budgets can only be computed currently for the following reaches: Lees Ferry to Little Colorado River, Little Colorado River to Bright Angel Creek, and Bright Angel Creek to Diamond Creek.

A synthesis of all existing water and sediment fluxes for differing reaches of the Canyon under differing dam operations is proposed. The objective of this synthesis is to relate fluxes by reach to side channel fluxes and where opportunities exist, related the integrated flux to mainstem biological resources.

Calculation of the above budgets also necessitates measurement and estimation of water and sediment inflow from tributaries. Stations on the Paria River at Lees Ferry and Little Colorado River near Cameron should be continued. Sediment from Moenkopi Wash, a major sediment contributor to the Little Colorado River, is not measured and consideration will be given to developing a measurement station at the Little Colorado River confluence. Sediment measurement stations will be established on other tributaries to the mainstem only if it is determined through research that these inputs have localized reach impacts to critical biological or cultural resources.

This is not necessarily the case for water discharge data, and gauges for these measurements on major tributaries might still be considered.

Chemistry and temperature changes of water in the mainstem of the Colorado influences many aquatic biota and biological processes. Changes in water chemistry and temperature may alter physiological processes of aquatic biota, potentially triggering changes in the aquatic trophic dynamics of the Canyon. The water chemistry of the mainstem below the dam is influenced by: 1) nutrients trapped by Glen Canyon Dam, 2) changes in nutrient transport in Lake Powell that result from changes in lake level, and 3) in the mainstem resulting from water transport fluxes. Thus, the objective of water chemistry monitoring and research is to describe the aquatic environment of the Canyon, and evaluate this in terms of maintenance of riverine ecosystem components deemed critical by the resource management agencies and interests such as, fish, aquatic food base, and riparian vegetation.

Evaluation of chemical and biological changes in the riverine ecosystem are dependent, in part, on river discharge, water temperature and sediment data collected at the monitored gauges on the mainstem and at the point of discharge from the dam. Basic data on water temperature, conductivity and pH will be measured at these gauges and at the dam at the same time intervals established for sampling discharge and/or sediment transport. Measurements of dissolved oxygen, particulate and dissolved organic matter, and nitrogen and phosphorus will be made seasonally.

Research efforts most needed are modeling of water quality changes through the canyon under differing operating criteria. Most needed are algorithms for temperature, water chemistry and biology as related to differing operating criteria.

Mainstem and Tributary Interactions.

Interaction of Mainstem and Tributary water and sediment is influenced by dam operations primarily at their confluence with the mainstem. In addition to the influence on flows at the confluence, tributaries are an input of both inorganic and organic materials to the mainstem. As such, the objective for long-term monitoring and research on tributary characteristics is to evaluate possible causes of mainstem changes, that is, operational causes versus tributary influences. Tributaries of the Colorado River area may provide refugia for native fish, trout and other non-native fishes, as well as riparian ecosystems. For this reason, they are included in the long-term monitoring and research program. They are considered controls for evaluating changes in selected attributes in the mainstem (e.g., aquatic biota), and as a source of attribute inputs.

Tributary inputs to the mainstem include hydrological, sediment and limnological attributes. Not all tributaries can be monitored, thus emphasis will be limited to those with major inputs, either abiotic or biotic. In addition to water and sediment discharges from the Paria and Little Colorado Rivers mentioned earlier, tributary discharges, water chemistry and biological attributes will also be monitored. Further, these measurements are also planned for Kanab, Bright Angel, and Havasu Creeks. Measurements will be continuous for discharge rates, seasonal for chemical and biological attributes, and they will be taken in conjunction with the measurements at the gauges in the mainstem. Discharge monitoring will require maintenance, reinstallation, or installation of gauging systems in the above tributaries. The necessity for this invasive technology should be evaluated against other less invasive technology. Especially with perennial flows, selected tributaries could be sampled quarterly for comparison with primary tributary and mainstem data. Measurements would be limited to water chemistry and biological attributes.

Sediment dynamics in the system represent critical resource attributes to many other resources. Sediment in the Canyon is either in transport or in storage above or below the river surface. Sediment transport flux is monitored periodically at gauge sites in the Canyon. Stored sediment in the channel and eddies is the source and foundation of elevated sediment deposits.

The prescribed dam operations in the ROD consider sediment accumulation in the river system, in the channel or eddies, and in elevated deposits (e.g., beaches). Therefore, the objective of monitoring changes in stored sediment is to evaluate the sediment budget predictions of the EIS relative to the selected alternative in the ROD. In order to determine the influence of dam operations on the integrity of these deposits, the objective of the monitoring program is to determine changes in sediment storage in different reaches of the Grand Canyon. The accomplishment of this objective will permit measurement of temporal change in the status of critical bar and bank sediment deposits and in debris fan deposits, and to place that change within the context of measurement of all sediment storage change in the Grand Canyon.

Sediment inputs from tributaries may not be similar to sediment that once traversed the mainstem. This impact to the river ecology is not related to dam operations, but may be critical knowledge in assessing what impacts are due to operations. A research study is proposed to evaluate this factor.

Selected sandbar and campsite beaches will continue to be measured annually to study the relationships between sediments resources and recreational beaches. Established survey techniques would be employed by trained surveyors. Measurement of short-term changes on bars, although of interest in determining sediment dynamics, is not the focus of the long-term monitoring program. Long term assessments will evaluate significant changes in mass in critical reaches and within the entire system.

Measurement of bar changes throughout the Canyon will be made using air photo interpretation and video imaging analysis strategies across multiple year periods. Such measurements permit wider ranging measurements using less invasive measurement strategies. Short-term repeat photography is not recommended as part of the long-term sediment monitoring program except perhaps at sensitive archaeological sites to determine change.

Mainstem and Lake Mead Interactions

Interaction of mainstem and Lake Mead Delta water and sediment resources represent significant potential areas of physical resource impacts due to variable dam operations. Assessment of impacts due only to dam operations may be difficult, however, due to confounding associated with operation of Hoover Dam. Assuming a consistent pattern of operations at Hoover Dam and somewhat stable water levels, variable operations of Glen Canyon Dam would produce differing long-term changes in physical, biotic, and cultural resources in the upper Lake Mead region. Inflows to reservoirs are often the most dynamic region of a reservoir's physical and biotic resources (BOR, 1995).

Defining resource impacts from dam operations in this region is, however, extremely difficult due to the influence of downstream dam operations on Lake Mead reservoir level.   Nonetheless, operating criteria changes such as the unplanned flows of 1983-1986 and the beach habitat building flow of 1996 function as a significant energy pulse, creating impacts to marsh zones, spawning beds, sediment deposits, standing biomass levels, riparian vegetation, etc. An area of monitoring research proposed for this interactive zone is to determine with remote sensing, short and long-term changes in sediment deposits, backwater and marsh habitats, riparian vegetation and primary productivity.

THE BIOLOGICAL RESOURCES PROGRAM

> *"Ecosystem degradation is not inevitable; it is simply cheaper and easier for some in the short term. Ecosystem health is also not inconsistent with economic imperatives and political realities. In fact, a healthy environment is the basis for a healthy economy."* Likens, G.E., 1992.

Introduction

Deciding what to measure, how, where, and when to measure and how to analyze and interpret the resulting data are some of the most critical issues to be addressed in the development of a long-term monitoring program for biological resources. To be successful, the long-term monitoring program must ensure that data collection, analysis, and interpretation will address specific management needs and objectives.

The Grand Canyon Monitoring and Research Center (GCMRC) has followed a process which is designed to ensure that the information produced will address the needs of managers and decision-makers. In addition, the iterative nature of the process used to develop management objectives and information needs will help ensure that the scientists and managers are in agreement over the most critical questions to be addressed.

The design of an effective long-term monitoring program is not a trivial task. Many case studies indicate that long-term monitoring programs are often confused with data collection activities that are part of research efforts. They are also affected by the difficulty in selecting appropriate parameters to measure and the appropriate approach to measurement. "For example, monitoring to measure degradation in fish communities could focus on the number of species in the community, community trophic structure, [population estimates,] the incidence of abnormalities, or many other parameters" (NRC 1990).

As pointed out by the NRC (1990) monitoring programs must be designed to discern change over time while accounting for variability and uncertainty in the system, and still produce data sets that can be analyzed to determine cause and effect relationships. In addition, monitoring needs to be dynamic so that monitoring needs can be prioritized and modified in response to what is learned from the ongoing monitoring and research activities, especially regarding the effectiveness of prescribed management actions, and in light of real-world scientific, logistical, and financial constraints (NRC, 1990).

Finally, the NRC (1995) has identified the development of a conceptual model as an essential step in the selection of environmental parameters to be modeled.

Program Elements. Three programmatic elements are required to develop the understanding of biological resources needed to effectively support the selection of appropriate management actions for achieving specified management objectives. These are: 1) inventory of the biological resource components of the Colorado River ecosystem within Glen and Grand Canyons and the development of a conceptual model of the linkages between the biotic and abiotic components of the ecosystem, 2) monitoring of ecosystem behavior, both short and long-term to determine if the models of the ecosystem are predictive, both in response to natural perturbations and alternative dam operations, and 3) research to explore cause and effect relationships, test alternative hypotheses, and develop an improved understanding of the ecosystem. These elements must be implemented iteratively with much feedback, (Figure 6.2, GCMRC Approach to Ecosystem and Adaptive Management).

Program Goals. The Biological Resources Program is intended to develop information about the structure and function of the Colorado River ecosystem within Glen and Grand Canyons, as well as the impacts of a range of alternative dam operations on the ecosystem, in order to provide the knowledge base required to implement ecosystem management strategies within an adaptive management framework. The development of a fundamental information base on the structure (components) and function (processes) of the Colorado River ecosystem in Glen and

Grand Canyons is prerequisite to prediction of ecosystem effects from alternative dam operations.

Information on structure and function

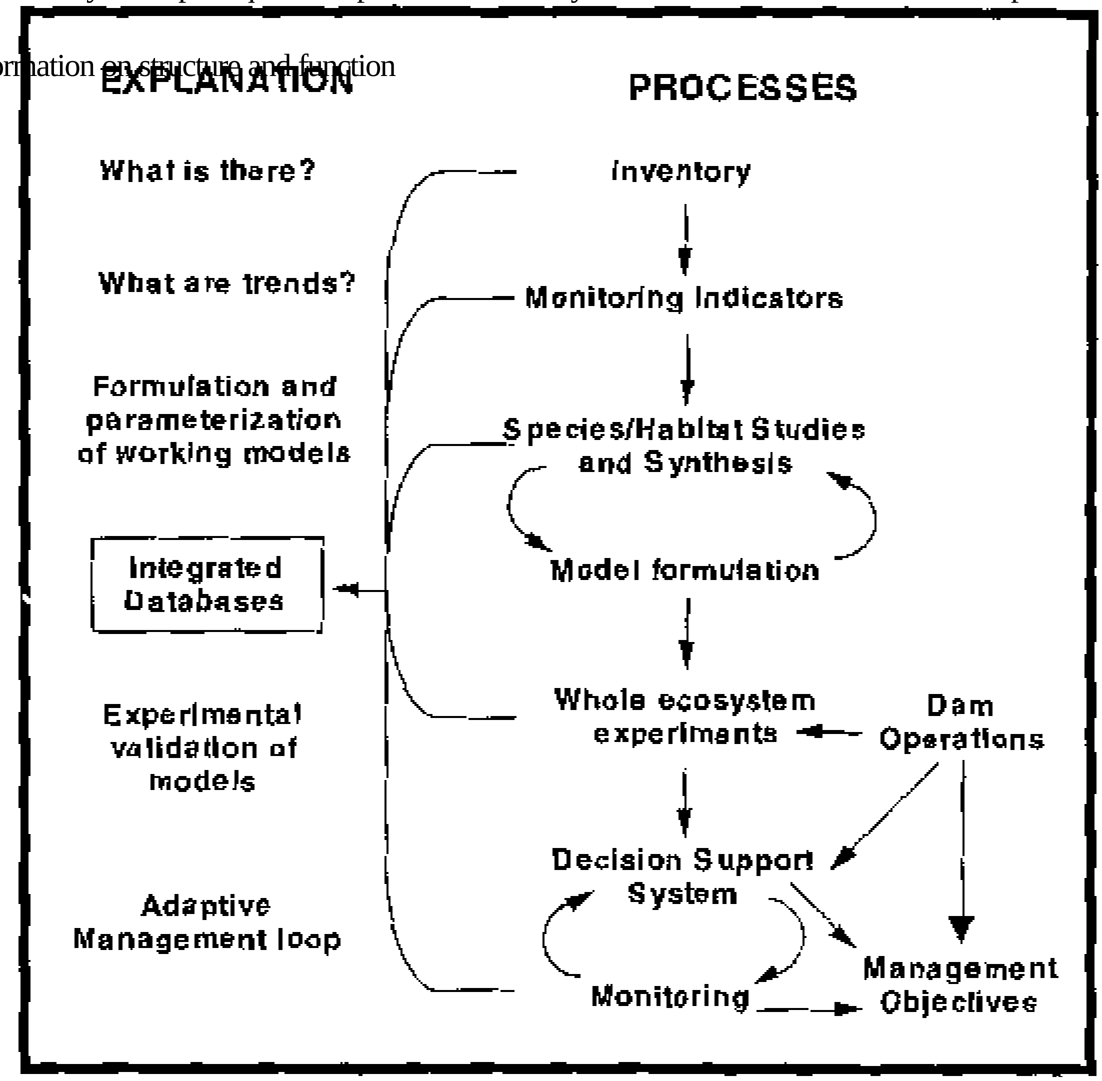

Figure 6.2. GCMRC Approach to Ecosystem and Adaptive Management (Adapted from CENR, 1995).

should include knowledge of the basic components of the ecosystem and an understanding of impacted and unimpacted ecological processes, both biotic and abiotic.

Candidate ecosystem components for monitoring can be displayed in relation to ecosystem structure in a diagram depicting patterns of activities within an ecosystem at different levels of complexity (Figure 6.3, Likens 1992). These processes include hydrology (current flow and ramping rates), water quality (DO, temperature, salinity, nitrification), habitat alteration, and population or community dynamics. Ecosystem components include species occurrence and distribution, and abiotic components such as hydrology, and water quality. It is key that relationships between the biotic and abiotic components of the Colorado River ecosystem in Glen and Grand Canyons be addressed, for without an understanding of those relationships, one will not be able to predict the effects of alternative dam operations on critical biological resources and the Colorado River ecosystem in Glen and Grand Canyons, in general.

Alternative dam operations may impact the Colorado River ecosystem in Glen and Grand Canyons in ways and on scales (temporal and geographic) not generally experienced in response to natural perturbations. Knowledge regarding the impacts of natural and anthropogenic factors on biodiversity and ecosystem dynamics, and the adaptation of communities and organisms to those factors, is needed in order to propose management alternatives for achieving specified management objectives.

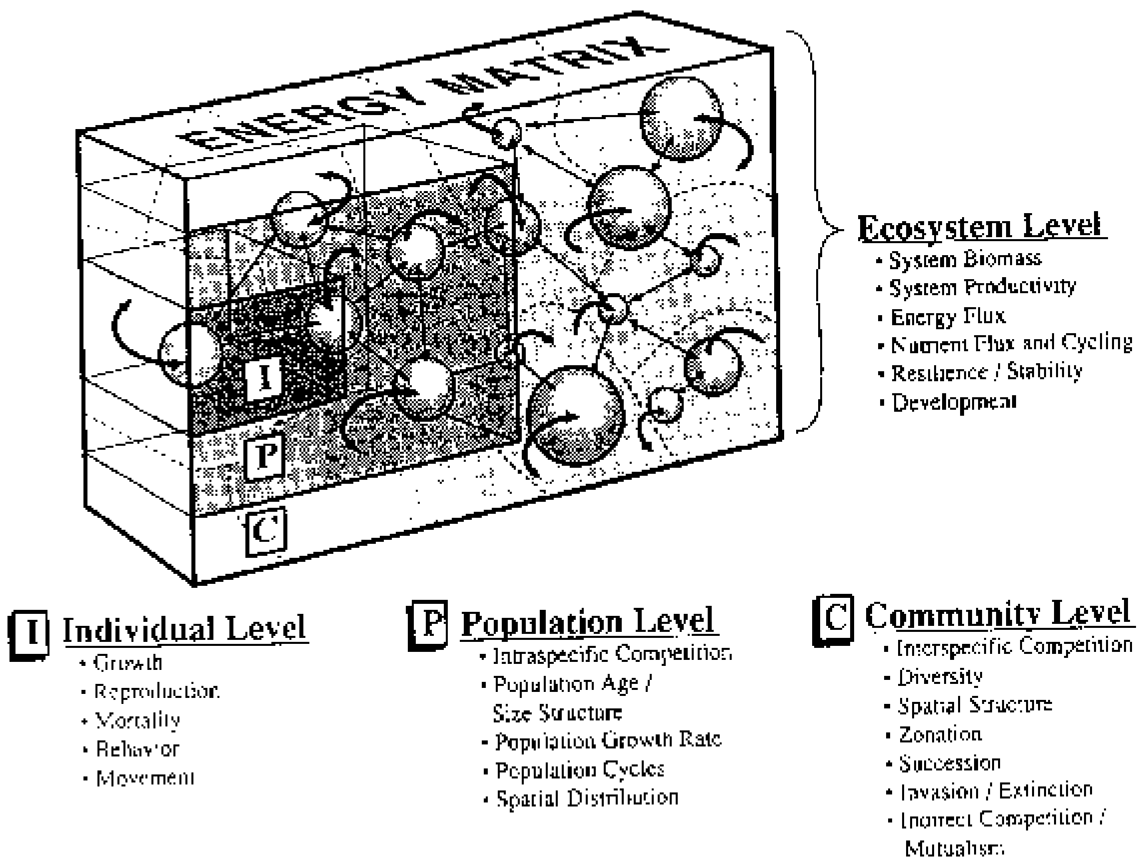

Figure 6.4. Diagrammatic conceptualization of patterns and activities at different levels of complexity. Each sphere represents an individual abiotic or biotic entity. Abiotic is defined as nonliving matter. Broad, double-headed arrows indicate feedback between entities and the energy matrix for the system. The thin arrows represent direct interactions between individual entities. Much of ecology is devoted to studying interactions between biotic and abiotic entities with a focus on the effects of such interactions on individuals (I), populations (P), or communities (C) of organisms. Ecosystem ecology studies these interactions from the viewpoint of their effect on both the biotic and abiotic entities and within the context of the system. The boundaries of the system must be established to conduct quantitative studies of flux. (From Likens 1992)

PROPOSED MONITORING AND RESEARCH ACTIVITIES

Aquatic Food Base

Many wildlife species, especially fish, depend on the aquatic food base for their survival. Fluctuations in aquatic food resulting from dam operations or other factors may trigger changes in some or all of the populations of native and non-native fish species. The long-term monitoring program should be designed to determine how the biomass, habitat, and composition of the aquatic food base will respond to alternative dam operations.

Development of an appropriate aquatic food base monitoring scheme will need to address changes in species survival and productivity, standing crop, and dominance and habitat requirements of aquatic invertebrates and algae. Physical condition, should also be considered for monitoring through the use of appropriate indicators.

Complementary with the biotic sampling, the appropriate abiotic parameters should be measured for comparison with abiotic data from the gauge sites.

Fish

Fish are an important part of the Colorado River ecosystem because of their trophic role, their important recreational value, and because some are listed as threatened or endangered under the Endangered Species Act.

The Colorado River's native and endangered fishes have been affected by environmental changes resulting from the construction of Glen Canyon Dam and subsequent power plant operations, and the introduction of non-native fishes, plants, and invertebrates.

Abiotic changes in the environment are thought by most researchers to be responsible for the present day status and condition of the native ichthyofauna. These changes -- which have resulted primarily from the operations of Glen Canyon Dam -- include reduced sediment transport, altered flow regimes, and reduced water temperatures. In addition, the altered flow regimes have lead to a change in channel morphology, including the degradation of backwaters thought to be important nursery habitat.

For a native fish population to remain viable, successful recruitment must occur. In general for fish, the timing of reproduction must coincide with local food production cycles, and larvae must be transported to a favorable nursery habitat. Management of river flows can affect larval transport to nursery grounds, and thereby influence recruitment. Both food production and nursery habitat quality are tied to physical factors such as temperature and nutrient supply, both of which are partially dependent on the timing of water releases upstream. Dam management practices resulting in low production of phytoplankton during normal times of fish spawning may negatively affect mean instantaneous growth rates. Slower growth rates increase the duration of high risk life stages, potentially increasing mortality and reducing recruitment.

The goals of the long-term monitoring and research program for fish resources will be to develop an understanding of the links among dam operations and the resulting flow regimes, spawning, larval transport, trophic dynamics, and recruitment.

An integrated state-of-the-science review and assessment of existing information on native and endangered fishes in Glen and Grand Canyons is being undertaken to identify factors that limit reproduction, development, recruitment or survival of native fishes in the Little Colorado River and its associated tributaries in Glen and Grand Canyons. This activity should lead to the development of information critical to the development of a conceptual model linking abiotic and biotic components of the system, as well as to identify key parameters for long-term monitoring and related research activities.

Long-term monitoring activities will seek to develop information that can be used to evaluate the status and trends of native fish populations in the Colorado River ecosystem in Glen and Grand Canyons and seek to collect data that can be used to assess the response of native and non-native fish communities to alternative operation of Glen Canyon Dam. These native fish species include: humpback chub (Gila cypha), razorback sucker (Zyrauchen texanus), flannelmouth sucker (Catostomus latipinnis), bluehead sucker (Catostomus discobolus), and speckled dace (Rhinichthys osculus). The plan will emphasize the endangered humpback chub and will seek to address concerns raised by the U.S. Fish and Wildlife Service in the Biological Opinion.

Data to be collected during this interim monitoring effort will include appropriate estimates of abundance, species composition, age structure, and reproductive condition. The sampling time frame should recognize the long- or short-lived nature of the species being monitored. Annual sampling should be conducted to coincide with appropriate seasonal activity and, if possible, correspond with sites selected for aquatic food base monitoring.

Humpback Chub. The humpback chub (Gila cypha) is endemic to the Colorado River basin in Colorado, Utah, and Arizona. Inundation of canyon habitats by mainstem dams, cold tailwater releases, altered flow regimes and introduction of non-native fishes have reduced its range and numbers.

The population of humpback chub in Grand Canyon is probably the largest and most reproductively viable population known Valdez and Ayel (1995), identified nine distinct aggregations of humpback chub located in the Grand Canyon. This population is concentrated in the mainstem Colorado River near the mouth of the Little Colorado River (LCR), With approximately 74 percent of the total numbers captured in this aggregation. This is the only aggregation that is known to be self-sustaining. Humpback chub are also found in low numbers in one location above of the LCR reach Fence Fault Springs (RM30), and seven locations downstream of the LCR reach, including upper Bright Angel Creek inflow (RM 87.7), Shinumo Creek inflow (RM 108.8), Middle Granite Gorge (RM 127), Havasu Creek inflow (RM 156.9), and Pumpkin Springs (RM 212.9). These other aggregations tend to be associated with springs or tributary inflows and are not known to be self-sustaining.

Other Native Species. Flannelmouth suckers and bluehead suckers may have been reduced in number and distribution in Grand Canyon since the construction of Glen Canyon Dam. These fish appear to spawn primarily in tributaries (LCR, Shinumo Creek, Kanab Creek, Bright Angel Creek, Havasu Creek) in March and April. The adults spend up to two months in tributaries during spawning, but relatively little is known of the larvae and young following hatching. Flannelmouth and bluehead suckers are found throughout the Grand Canyon, although large pre-spawning aggregations have been seen at the mouth of Kanab Creek.

The razorback sucker is very rare in Grand Canyon. It is thought that only a few old and senile adults remain in such low numbers that the species can be considered biological extinct from the region. However, the possibility exists for razorback suckers to occupy the lower reaches of the Colorado River just upstream of the Lake Mead inflow (Separation Canyon to Pearce Ferry) and this area has been suggested as a potential recovery habitat for this species.

Little is known about the biology of speckled dace in Colorado River ecosystem in Glen and Grand Canyons. The species is ubiquitous throughout the western US, but little has been synthesized on its status and trends in Grand Canyon. Speckled dace are most common in riffles and rocky shorelines, but are also found in tributaries, silt-substrate backwaters and shorelines.

Possible Monitoring Objectives . The hydrograph of the LCR should be monitored to examine the relationship between flow timing, magnitude, sediment load and year class strengths. Maintenance of the LCR stream gauge may provide the data needed to examine the relationship linking river flow with reproductive success.

Young humpback chub are commonly found in backwaters (i.e. pools formed in tributary months and/or low-velocity areas formed behind sandbars) and have been assumed to use them as nursery habitats if these habitats are warm, turbid, and sheltered from mainstream inundation or desiccation. Humpback chub do not use these habitats exclusively; they also use adjacent sheltered talus shorelines. Nevertheless, backwaters are relatively permanent features that can be sampled and may provide data which can be used as indices of year class strength, survival, and individual growth.

Survival of cohorts (year classes) and recruitment into the adult population is vital to the existence of humpback chub in Grand Canyon. Since this species appears to be long-lived (20 years or more) and adaptable to changing habitat conditions as adults, recruitment to adult age (3 to 4 years) probably greatly enhance fitness. Understanding the survival of cohorts is important to monitoring in order to identify factors that may limit that survival, particularly if they are flow-related.

Monitoring the relative abundance of adult humpback chub provides an index of the long-term trend of the population. This trend is usually determined by biotic factors such as condition (health), year class strength, food availability, and diseases and parasites; as well as abiotic factors such as water quality and habitat stability. Most factors that affect adult population size are not manifest for several years, and so assessment of year class strength, survival, etc., is important to understanding causative factors leading to long-term population trends.

Habitat quality, selection, and use by many species of native as well as non-native fish should be examined. Backwater habitats are assumed to be particularly important as nursery areas for young native fishes, but are also used extensively by many non-native fishes. Backwaters under fluctuating flows can be short-lived, as they are inundated or desiccated on a daily basis. The short and long-term existence of these habitats is vital to the life history of many fish species.

Similarly, shorelines with talus, ledges of Tapeats or vegetation are frequently occupied by native fish and may offer shelter from predators, provide immediate sources of food, and protect the fish from rigors of mainstem flow. Young fish can be easily displaced when flows exceed habitat requirements (e.g., velocity becomes too great from rising flows or shoreline rocks become exposed with descending flows). Like backwaters, shoreline habitats can also be monitored to determine the flow releases most suitable for maximum habitat development.

Finally, non-native fishes in Grand Canyon are thought to pose a threat to the native species with competition for resources, predation, and parasites and diseases. The various non-native species have different effects. Monitoring should be conducted to determine how alternative dam operating scenarios could effect non-native species and may prevent further intrusion by these fishes into the Grand Canyon ecosystem.

Trout

Trout were first introduced into tributaries of the Colorado River ecosystem in Glen and Grand Canyons during the 1920s. Seasonally warm water temperatures and high sediment loads probably precluded their sustained use of the mainstem prior to closure of Glen Canyon Dam. Stocking of trout below Glen Canyon Dam began in 1964 and has continued to date. Natural reproduction commonly occurs but may be insufficient to sustain desired trout numbers.

The 25 km reach below Glen Canyon Dam is managed as a blue-ribbon fishery with emphasis on production of trophy-sized trout. Although trout occur throughout the Colorado River and several tributaries in Grand Canyon, recreational fishing below Lees Ferry is quite limited compared to the upstream reach.

Alternative dam operations and the resulting flow regime can directly and indirectly affect trout found in the dam tailwater. Indirect effects involve ecosystem processes and lower trophic levels which provide the food base for the fish. Direct effects include stranding of all life stages in isolated pools, dewatering of spawning and rearing habitats, and displacement of individuals from preferred habitats. Stranding and dewatering are sources of mortality for adults, juveniles, and larval fish, while displacement may cause increased energy expenditure, reduced food intake, and disruption of reproductive activities.

Monitoring of trout should concentrate on growth, survivorship, and changes in population structure, including the contribution from natural reproduction, over time. Emphasis should be placed on the trout population above Lees Ferry. Downstream sampling may be accomplished in conjunction with monitoring activities for native fish.

Development of an appropriate trout monitoring scheme will need to address the frequency of sampling (i.e. seasonal, following annual flow events, etc.). Creel data and regular surveying of fish guides may be used to supplement trout monitoring data gathered above Lees Ferry.

Riparian Vegetation

The riparian vegetation communities along the Colorado River and its tributaries are important for stream bank stability, fish and wildlife habitat, and aesthetic and recreational values. In addition, certain Tribal groups view some botanical resources as traditional cultural resources. Those along the mainstem of the Colorado River are composed of three distinctive communities: 1) upper riparian zone (URZ), 2) lower riparian zone (LRZ), and 3) hydro-riparian wetland communities. For long-term monitoring purposes, all three community types should be included; however, because of the different response rates of these communities to changes in the river dynamics, monitoring procedures (especially timing) should differ. Management of species responding to strong environmental signals will be enhanced by improving the understanding of the physical or biological factors forcing biological changes, so that options can be explored for implementing adaptive management strategies.

Development of an appropriate riparian vegetation monitoring scheme will need to address the location, size, frequency, and method of sampling.

Annual video photography and aerial photography of the Colorado River corridor in Glen and Grand Canyons has been used to map riparian vegetation in the GIS reaches established by the GCES program and is being evaluated for use in quantifying changes in cover and composition. These data will be linked with equivalent monitoring of sediment (and beach) changes through GIS.

Riparian Fauna

Riparian faunal habitat relations have not been well established in the Grand Canyon. Determination of faunal response to dam operations is extremely difficult and is dependent on knowing faunal response to changing ambient conditions. Thus monitoring of faunal assemblages should be aligned to sampling of riparian vegetation habitat changes.

Invertebrates

Terrestrial invertebrates along the Colorado River in Grand Canyon provide essential food resources for riparian insectivores (insects, amphibians, reptiles, birds and mammals), thereby linking vegetation, productivity and habitat conditions with secondary consumer population dynamics. Glen Canyon Dam significantly increased the stability of riparian habitats, undoubtedly permitting an increase in terrestrial invertebrate populations. The biotic inventory of invertebrates is far from complete, with numerous undescribed endemic taxa still likely to be discovered.

Monitoring of selected key taxa would permit evaluation of changes that may be a response to dam operations. Inventorying of the invertebrate fauna, if undertaken at all, should be coordinated inventory programs of the NPS. As part of a long-term research program, one should consider establishing the associations between invertebrate assemblages (e.g., using selected taxa) and different riverine and shoreline vegetational communities. In this way, long-term monitoring of these vegetation communities can be used as a surrogate for determining response of invertebrates to operational changes in the Grand Canyon.

Vertebrates

Terrestrial riparian vertebrate populations in the Colorado River corridor in Grand Canyon are trophically significant secondary consumers, integrating habitat conditions to invertebrate and other primary consumer populations. The Colorado River corridor supports high densities of terrestrial/riparian vertebrates and populations of many species are changing. More than a dozen native vertebrate taxa have recently been lost, or are of unknown status in this system, and several native and non-native species populations have increased in recent years. Terrestrial vertebrates are relatively easily monitored, exert significant trophic influences on ecosystem structure, and are recognized as priority resources by the NPS. Avifauna are especially conspicuous and are trophically significant secondary consumers, integrating habitat structure, food resource production and predator populations. The Grand Canyon serves as an important flyway and stopover location for migratory waterfowl, raptors and passerine species; however, monitoring has been inconsistent. Several avian species are federally listed as rare and endangered, or are considered for listing, including bald eagle, peregrine flacon, Southwestern willow flycatcher, etc. Therefore, vertebrate species deserve monitoring attention.

The intensity of effort required for vertebrate (herpetofauna, mammals and birds) population sampling precludes sampling at all long-term vegetation study areas and requires a focus on the habitat relations of selected assemblages of vertebrates, especially herpetofauna and birds. Development of monitoring programs for vertebrates will require additional study.

Birds

Avifauna inventory and monitoring should emphasize listed species (e.g., southwestern willow flycatcher), wintering and breeding waterfowl, riparian obligate species, resident non-obligate species, and migrant species in a biogeographic/ geomorphic/seasonal context. New, dam-created riparian habitats (e.g., tamarisk stands and marshes) are being colonized for nesting, while the status of avian use in the upper riparian zone is poorly known.

Common taxa can be readily monitored on plots, while waterfowl, shorebirds, migrating raptors and wading species can be monitored while floating through the river corridor. These data, in concert with regional population data, will permit systematic evaluation of changing populations sizes.

THE CULTURAL RESOURCES PROGRAM

Introduction

The cultural resource program is charged with designing and implementing monitoring and research activities that assess cultural resource impacts related to “dam operations” as specified in the GCDEIS/ROD. Stakeholder objectives and information needs for the program are developed with AMWG and Technical Work Group members and then formulated into monitoring and research activities for the GCMRC’s strategic plan. The GCMRC provides this information to the AMWG to assist them in formulating their recommendations.

Based on the GCMRC’s authority and responsibility to seek out new information, the cultural resources program includes elements that address monitoring of identified resources that are believed to be currently impacted by “dam operations.” These activities form a part of the larger cultural resource program that includes tribal participation in resource assessments and research, data management and information dissemination.

The GCMRC cultural resource program complements the legal compliance program of the BOR and NPS. The NPS and the BOR have specific legal responsibilities to ensure the protection of historic properties within the Grand Canyon National Park and Glen Canyon National Recreation Area as specified in federal cultural preservation legislation. These laws include the National Historic Preservation Act (NHPA), the Archaeological Resources Protection Act (ARPA) and the NPS Organic Act. The responsibilities specified within this legislation can not be delegated or abrogated by these agencies. The BOR responsibilities include assessment and mitigation of the direct affects (both positive and negative) on historic properties (as defined in the NHPA) of the water releases associated with dam operations. The NPS responsibilities include the management and administration of historic properties through resource inventories, resource assessments, and monitoring activities in the river corridor below the Glen Canyon Dam.

These responsibilities are coordinated and described in the Programmatic Agreement (PA) that, defines and specifies the legally binding responsibilities of these agencies to maintain compliance relative to the NHPA. The PA was established as a cooperative effort among Native American tribes, NPS, BOR, Advisory Council on Historic Preservation, and Arizona State Historic Preservation Office. The PA documents general procedures and requirements for mitigating adverse impacts on historic properties including the traditional Native American cultural resources in the Colorado River corridor below Glen Canyon Dam resulting from "dam operations." The document implementing the PA requirements is the Historic Preservation Plan (HPP). The PA represents a landmark process involving closely coordinated activities among eight tribal nations, the NPS and the BOR.

As stated in the GCDEIS [pg 36], the cultural resource activities of the GCMRC will be conducted in accordance with the PA stipulations to ensure integration and compatibility between the PA program as articulated in the HPP and the cultural resource program. Both programs provide complementary information.

However, the GCMRC's cultural program is more broadly defined. While the BOR and NPS legal compliance program specified in the PA is strictly limited in scope to previously-defined resources, the GCMRC cultural program generates new monitoring and research data concerning a broad range of cultural resources including archaeological, ethnographic, ethnobotanical, faunal, and physical resources. In addition, tribal assessments, research, data management and information dissemination are included within the program. Figure 6.4 diagrams the relationships between these programs. Path "A" indicates redirection of PA activities into the AMP. Path "B" diagrams the linkage between the GCMRC program and services provided by the PA parties. Information sharing is also shown as a continuous loop between both programs.

Projects and activities included within the GCMRC's cultural program will be funded through its funding allocations from WAPA power revenues that are currently managed by the BOR and subject to budgetary recommendations by the GCMRC and AMWG and approval by the Secretary.

GCMRC Program activities will be formulated from stakeholder objectives and the information needs that were developed in consultation with the members of the AMWG. The tribal, BOR, and NPS PA signatories are members of the AMWG. As members of the AMWG they should discuss and prepare recommendations to the GCMRC for needed projects that are consistent with the identified objectives and information needs. They may elect to have projects that include PA activities, incorporated within the GCMRC program by channeling them through the AMWG. The Cultural Program Manager will act as a liaison in conveying program information from the GCMRC and assisting in recommendations to the GCMRC. Consequently, to the extent that the required PA activities coincide with the activities of the cultural program of the GCMRC, they may be fundable by the GCMRC, subject to allocations in the annual program plan. As needed, projects will be prioritized based on GCMRC protocols. These protocols relate to integration and coordination between the interests of the AMWG, and the GCMRC; monitoring and research priorities; funding approvals; proposal submittal and technical review; contracting and interagency agreements; report submission; and data archiving and distribution.

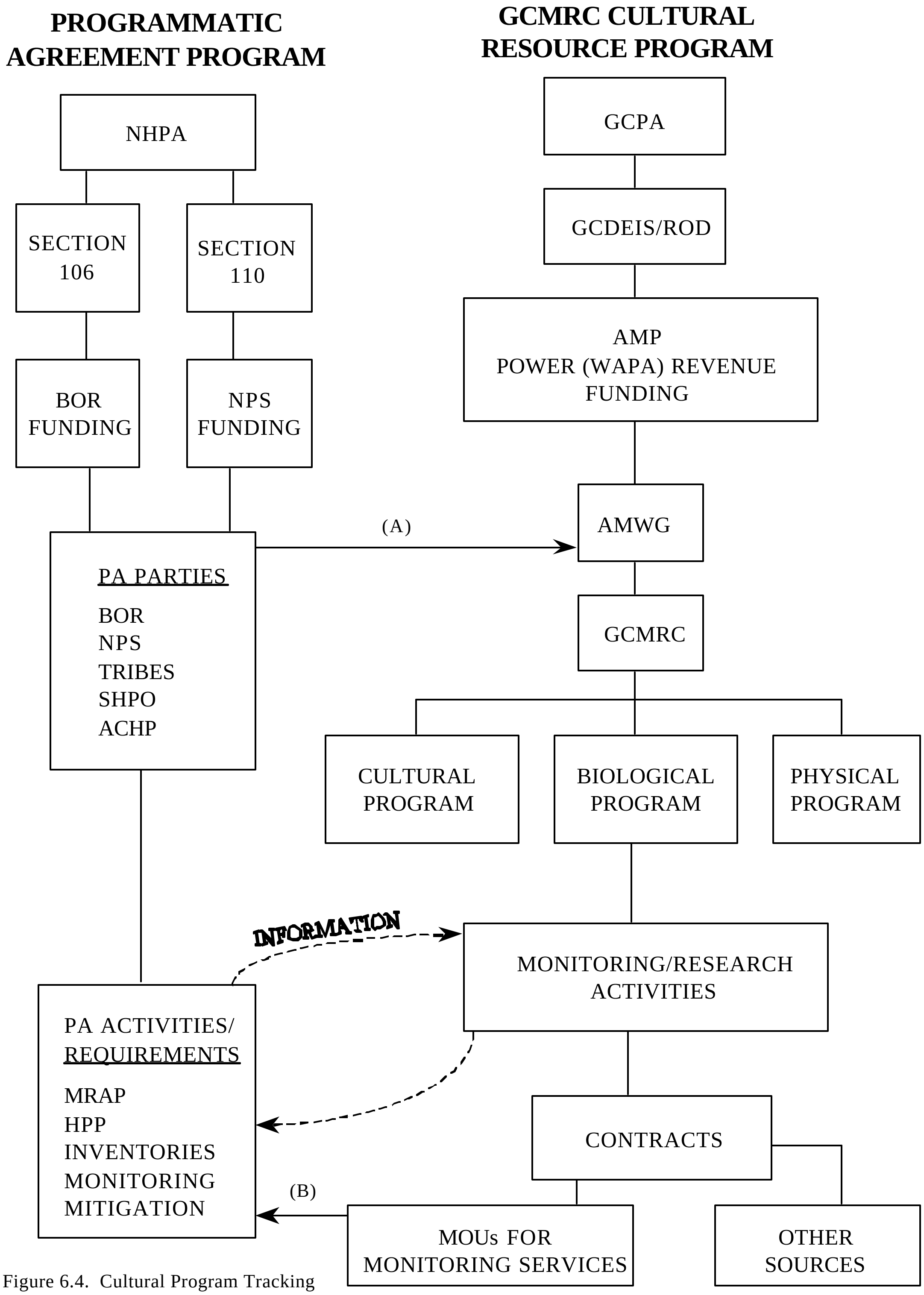

Figure 6.4. Cultural Program Tracking

PA activities that are not funded under the GCMRC program, remain the responsibility of the BOR/NPS as they are legal PA requirements of those agencies. Funding recommendations by the AMWG pertain only to GCMRC activities as the AMWG has no authority concerning the PA program. PA activities that are not funded as GCMRC activities, return to the legally-responsible agency for implementation and funding.

The cultural resources program will also integrate with the other GCMRC programs. The Program Manager will function as a liaison with the other programs to assess project proposals that may have cultural content. Because the GCMRC definition of cultural resources includes biological and physical elements of traditional cultural importance to the tribes, the Program Manager will serve as an initial reviewer for proposals that may have sensitive content. If these are identified, the proposals will be referred to the appropriate parties for assessment. The Program Manager will work to coordinate this review and work with all parties to facilitate project evaluation. In this sense, the Program Manager will serve both liaison and coordination roles.

Program Description

The cultural resource program consists of three primary components that include: 1) a core program of monitoring and research activities for a broad range of resources as directed by the AMWG, 2) a tribal projects component and, 3) a cooperative programming component (Figure 6.5). The program manager is responsible for the implementation of these elements to the Center's chief.

<u>A) Core Program</u>. The core program consists of monitoring and research activities designed to address the stakeholder objectives and information needs identified through discussions with the AMWG. The proposed activities represent investigative strategies to address monitoring and research issues that derive from the stakeholder objectives and information needs identified within the AMP. The core program does not refer to the activities defined within the limited scope of the PA program unless these activities are channeled into the AMP by the PA signatories and specifically mentioned.

The core program activities build on information from monitoring and research activities related to past archaeological inventories as well as tribal monitoring programs that have been, and are, conducted under the PA program. Examples of existing sources of information generated under the PA program include, site recordation using mapping techniques and photography, and remedial actions such as stabilization techniques. Data generated from the proposed activities will be used to formulate future annual plans as well as modification to the long-term plan (OR: shall be incorporated into the long term monitoring plans).

Research measures may need to be formulated when monitoring activities have detected impacts to resources that are thought to be related to dam operations. These activities may include the full range of investigative strategies including testing, sampling, and full data recovery. Monitoring and research activities will be developed in consultation with the cultural resource component to of the AMWG.

New resources may be encountered during activities conducted under this program. These resources must be characterized when they are encountered and some research studies may be necessary to determine their important qualities that may be impacted by dam operations. The Native American tribes and federal agencies will be involved in these efforts. These research studies, although less extensive than the monitoring program, are an important part of the program.

The second part of the Core Program is implemented by tribal members of the AMWG. Tribal groups shall design and implement their monitoring programs to evaluate the condition of their traditional cultural places and resources within the riverine corridor based on dam operations. These programs will conform to the long-term and annual plans developed by the GCMRC. Because the values associated with these places are known and understood by tribal individuals, the GCMRC recognizes that Native Americans are the most appropriate authorities to formulate programs that address their concerns about dam related impacts to these resources. Because of the sensitive nature of these places, information about the sites may be restricted both within and outside the Native American tribe. As such, these portions of the monitoring program and the information related to these monitoring and research projects with these segments are known only by the tribal nations, and in some cases only specific members within the group. Specific procedures will be developed between the tribes and the GCMRC where information about resource significance and locations can be protected.

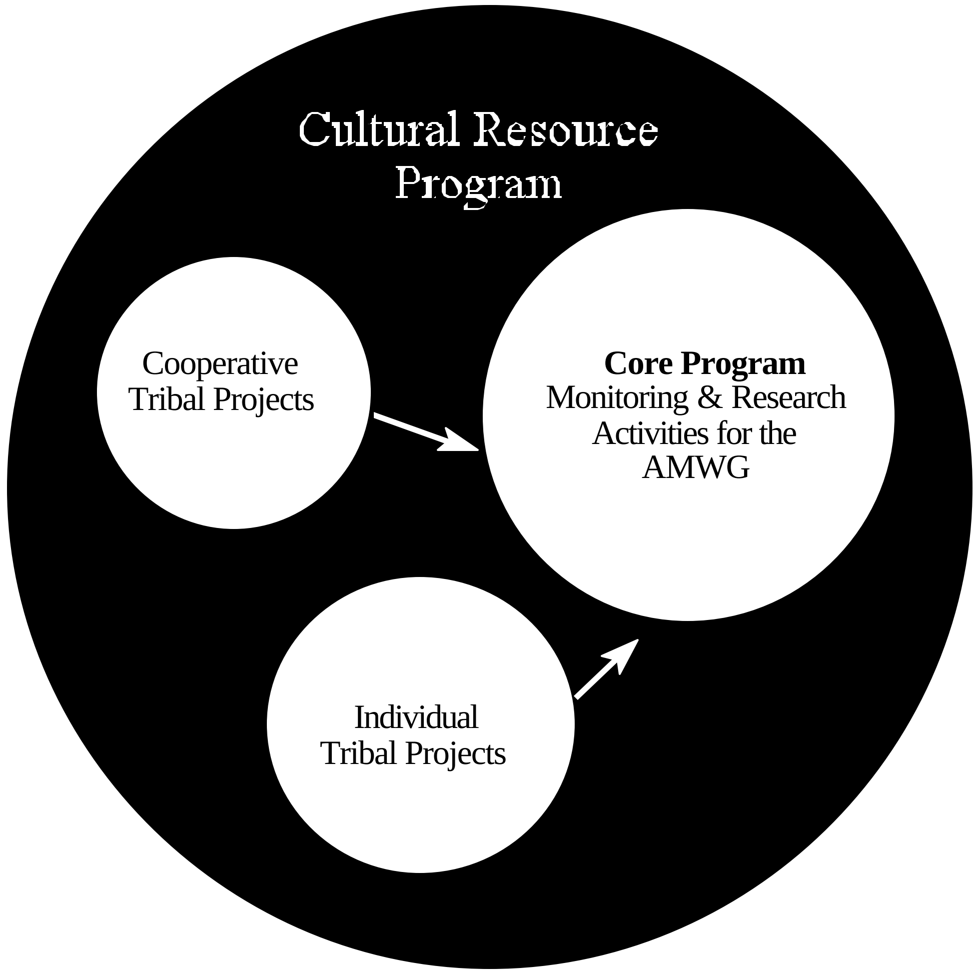

Figure 6.5. Primary Components of the Cultural Resources Program.

The ongoing monitoring and research efforts and the tribal activities associated with assessments of traditional cultural places may coincide with the NPS and BOR's requirements under the PA to address resource impacts from dam operations. Information derived from these activities will assist the GCMRC in meeting its requirements to provide the AMWG with information to formulate recommendations to the Secretary. These activities may also provide assistance to the NPS and the BOR in meeting their legal responsibilities.

The core program will be managed by the GCMRC Program Manager. Based on identified stakeholder objectives and information needs, annual work plans will be developed by the GCMRC. These work plans will be transformed into work contracts. The project proposal responses will be assessed for monitoring and research activities will be conducted by a team. The team will include representatives from the AMWG and the cultural resource program manager. Team evaluations will be forwarded to the Program Manager and the Chief where final approvals will be made. A team approach is critical to the continued development and enhancement of this core program. The leadership and knowledge represented by individuals in the tribal nations, NPS and the BOR is vital to the success of this aspect of the program. This mechanism will provide a collaborative approach for assessments of proposed actions under this program. Due to the GCMRC's funding allocations and the associated authorized technical reporting (ATR) responsibilities, the GCMRC must take final responsibility for proposal review and approval. However, proposal review and approval will involve full participation and input of team members.

B) Individual Tribal Programs. A second major element of the cultural program includes individual tribal programs that may enhance monitoring and research activities. Opportunities exist for the tribes to enhance and enrich their monitoring and research programs through projects that focus on additional monitoring technologies, indirect impacts to resources, or alternative investigative paradigms. Some examples of monitoring technologies include GIS mapping projects and locational studies, historical documentation and research, and traditional histories. Studies of resources that may be indirectly impacted may be included in this portion of the cultural program. For example, resources that are impacted by dam operations may have unknown contextual relations with other nearby sites and/or resources that are not directly impacted by dam operations. Studies of the context of the resource that is suffering degradation may include other resources that are believed to be related but indirectly impacted. These more comprehensive studies will contribute to the full understanding of the significance of the impacted resource.

Finally, projects that propose integrative and/or alternative investigative studies are encouraged by the GCMRC. These projects may investigate resources that have cultural values to Native Americans but are outside western notions of cultural resources. One example of this type of resource is a sacred plant gathering area that has important cultural values to a particular group but may appear as a biological resource from a western perspective. In addition, the GCMRC is interested in projects that incorporate traditional methods with conventional scientific methods to formulate new investigative methods and insights that reflect Native American perspectives and complement a conventional scientific approach.

If tribal groups are interested in submitting proposals that extend outside the scope of the GCMRC's funding ability, the Program Manager may assist tribal applicants with portions of the project that may not be directly funded by the GCMRC but are related to the GCMRC's operations by linkages to resources being studied for dam related impacts. In this manner, the Program Manager will function in a coordinating role for total program integration through assistance in research planning and proposal preparation.

Although this element of the cultural program may be less prominent in the total program, it is considered an important part of the overall cultural program. In addition, this element helps to implement an important goal of the cultural program; that participating tribal groups are full partners in the development and implementation of strategies to assess, evaluate, and protect cultural resources in the river corridor.

C) Cooperative Programming. Although the core program incorporates cooperative planning and programming for monitoring activities, most of the elements of the monitoring and research programs are individualized to specific tribes. This is also true of project proposals initiated by tribal groups to enhance their individual monitoring and research projects.

There are potential areas of interest to the tribes wherein the community of tribes may have common interests in both developing and participating in research planning and programming. These efforts could enhance monitoring and research capabilities, as well as, provide additional information regarding tribal associations with the Glen Canyon National Recreational Area and Grand Canyon National Park areas.

One example of an potential area of common programming interest is the development of educational opportunities for Native American students, particularly the participating tribal groups. These opportunities may include the development of cooperative educational agreements between the GCMRC, universities and agencies, and the tribes to involve students in intern programs that are related to all resources subject to monitoring and science activity in the canyon. These activities will complement the educational efforts developed within the PA program.

Scientific assessments in the last 15 to 20 years have developed significant information on the resources in the canyon. Within these scientific studies there have been some efforts to utilize these important monitoring and research programs to train new scientists, however, this has not been a focused effort of programming. The Native American community has increasing interest in utilizing ongoing study opportunities to develop improved scientific capabilities among members of their communities. The GCMRC is interested in the participation of the Native American communities in the research process and it will actively work with them to provide opportunities within the cultural program.

Finally, the GCMRC is concerned with the appropriate dissemination of monitoring and research information. Public funding supports the GCMRC's efforts to investigate resource impacts from dam operations and the GCMRC will work with the Native American communities to develop appropriate mechanisms for public outreach. Some examples of projects suggested in this portion of the cultural program include publications in varying formats for information dissemination to tribal members, student outreach field trips and visits, and workshops developed by the

GCMRC and Native American hosts to present differing perspectives on canyon resources and dam operations.

In conclusion, the cultural program consists of three major components: 1) monitoring and research activities to respond to objectives and information needs of the AMWG, 2) individual tribal projects, and 3) general Native American issues, such as education opportunities and public outreach. Following the ecosystem paradigm, the cultural program maintains an integrative and inclusive definition of cultural resources as defined by tribal participants in the adaptive management program. As such, the cultural program interfaces with other program projects to consider the concerns of tribal groups. Finally, the GCMRC views the program's monitoring and research requirements as opportunities for full tribal participation in the research methodologies and products.

The cultural resource Program Manager has an additional responsibility that requires increased cooperation with the Chief and other Program Managers. The cultural resource program has a requirement to function as an umbrella program across all tribal resource areas of interest or concern. The cultural resource program manager is required to coordinate all resource programs of interest to Native American tribes with federal agencies, state agencies, etc. It is anticipated that the program manager will accomplish program coordination via strong interaction with the physical and biological Program Managers and the Chief. Although the major part of the cultural resource program will not involve extensive coordination across resource areas, selected areas will require significant coordination. It is expected that all program managers will, through a team effort, keep all other program managers abreast of cultural resource monitoring and research planning and program direction, research support, and integration needs.

Status of Knowledge

The current status of knowledge concerning cultural resources is based on a number of previous investigations within the Colorado river corridor in the Glen and Grand Canyons. Comprehensive overviews of previous investigations are included in Ahlstrom et.al (1993) and Fairley et.al. (1994). Archaeological remains were first noted in the river corridor by Euro-Americans during the Powell expeditions in the 1800s (Powell 1875). Traces of archaeological remains were noted in the vicinity of Bright Angel Creek and the Unkar Delta area. In later years, archaeological investigations were noted in the river corridor and on the rims of the canyon (Hall 1942; Haury n.d.). In the 1950s and 1960s, investigations became more focused under the direction of the NPS, in part due to anticipated dam development in areas of the Canyon (Euler 1967; Euler and Taylor 1966; Taylor 1958). In the late 1960s and early 1970s the School of American Research and the NPS conducted excavations in the river corridor and adjacent areas to investigate the prehistoric settlement pattern (Jones 1986; Schwartz 1965; Schwartz et al. 1979, 1980, 1981). Together, these studies provided the initial information that suggested that numerous cultural resources existed within the river corridor.

Intensive archaeological inventories were conducted by the NPS during 1990 to 1991 in preparation of the GCDEIS to assess a range of dam operations (Fairley et.al 1994). These inventories located approximately 475 sites within the assessed area extending from Glen Canyon

Dam to Separation Canyon, about 225 river miles and up to the 300,000 cfs flood level. Of the sites within this area, approximately 336 had identifiable impacts that were believed to be related to dam operations. Impacts were categorized as direct, indirect, or potential. Direct impacts included sites where inundation or bank cutting had occurred within the site in recent years. Indirect impacts included: 1) bank slumpage or slope steepening adjacent to the site, 2) arroyo cutting or other erosion phenomena related to base level lowering from river eroded sediments within the site, and 3) effects of visitor impacts at sites due to recreational use patterns. Potentially impacted sites include those within the 300,000 cfs flood level without direct or indirect impacts currently identifiable.

Participating Native American tribes have also conducted cultural resource inventories to identify resources that have important cultural values to them. These studies were conducted by the Hopi Tribe, the Hualapai Tribe, the Navajo Nation, the Southern Paiute Consortium, and the Zuni Pueblo. Numerous locations of cultural importance were identified and assessed including important biological cultural resources, physical features and locations, and archaeological resources. Assessments were conducted by these tribes to identify impacts resulting from dam operations and to formulate possible treatment options.

Following the above resource inventories to establish baseline conditions, monitoring activities have been conducted to identify changes in resource conditions. The NPS conducts monitoring throughout the year and produces annual monitoring reports for the Glen Canyon and

Grand Canyon areas. Tribal groups conduct monitoring trips several times a year and assess changes to traditional cultural resources.

Current monitoring procedures include site visits, photographs, study units to observe artifact movement, and instrument mapping of sites. Results of these monitoring activities indicate that physical and visitor-related impacts constitute the majority of impacts to the cultural resources. Physical impacts include surface runoff erosion, side arroyo erosion that is often attributed to lateral bank retreat and bank slumpage, changes in vegetation, and in some cases direct inundation of the site. Visitor-related impacts include trails across site areas with resulting erosional effects, camping within site boundaries, graffiti at rock art locations, and collections and piling of artifacts. Animal related impacts have also been observed.

Recommendations from monitoring efforts include changes in monitoring scheduling, site or feature testing, surface collection of artifacts from sites for analysis and curation purposes, development of defined trails and obliteration of others, site stabilization and erosion control, site patrols, and measures to educate the public.

Proposed Monitoring and Research Activities

The past work provides a knowledge base to formulate a long-term monitoring and research plan that addresses the AMWG objectives for cultural resources that may be affected by the dam operations. The objectives are listed on the resource sheet located in Appendix A and include the following:

1) Preserve *in situ* all the downstream cultural resources and take into account Native American cultural resource concerns in Glen and Grand Canyons.

2) If *in situ* preservation is not possible, design mitigative strategies that integrate the full consideration of the values of all concerned tribes with a scientific approach.

3) Protect and provide physical access to and use of traditional cultural properties and other cultural resources used for religious purposes, by the participating Native American Tribes and traditional practitioners.

4) Develop, maintain, and integrate available cultural resources data recovered from monitoring, remedial and mitigative actions into evolving research designs for understanding human use and occupation in the canyon.

The above objectives were developed in consultation with a technical subgroup of the AMWG composed of individuals with cultural resource expertise. Information needs were also developed with the group to assist in meeting the objectives. The information needs can be summarized as the need to 1) develop data and monitoring systems to assess impacts, 2) develop data to assess risk of damage and loss from varying flow regimes, 3) develop tribal monitoring programs for the evaluation of impacts to cultural resources, 4) develop a predictive model of geomorphic processes that are related to archaeological site erosion, 5) develop mitigation strategies for sites with documented impacts from dam operations, 6) characterize resource values through directed study.

Each of the information needs developed with representatives of the AMWG is supported in the long term program by monitoring and research project activities. These activities are organized around the identified needs cited above.

<u>1) Develop data and monitoring systems to assess impacts</u>. Monitoring data has been collected on cultural resources by the NPS for several years. As a result of the GCDEIS process, monitoring activities were increased and became more standardized. This information was synthesized to provide direction for activities in the PA program. Since the cultural resource survey in 1991, the NPS and tribal groups have continued to monitor resources several times a year under the stipulations of the PA program. In part, this information has been partitioned into areas where different entities have jurisdiction. The information gathered during PA monitoring activities needs to be compiled into the GCMRC's study area and synthesized. Baseline information needs to be reviewed to ensure that sufficient data exist for all sites having the potential of being impacted by dam operations. The existing monitoring data need to be synthesized and evaluated against baseline information. Some of the possible elements of the data organization include site location and physical context; site types (e.g., structures, features, scatters, prehistoric, historic, Traditional Cultural Properties (TCPs, rock art sites), monitoring frequency; monitoring techniques; monitoring history; etc.

This synthesis is required under the PA program, and the PA signatories, who are members of the AMWG, may request that the GCMRC cultural program undertake this activity. If so, this effort would represent an activity that would serve complementary purposes for both programs.

In addition, data on Isolated Occurrences (IOs) need to be included in this synthesis. IOs may represent the last remains of site materials, or they may constitute the first exposures of buried sites or individual episodes of use and occupation within the Canyon. Collectively, IOs yield information about past adaptations and how people interacted with their cultural landscapes. All of these data on sites and IOs should be summarized in qualitative and quantitative formats to provide basic information on the resource base.

2) Develop data to assess risk of damage critical threshold levels, and loss from varying flow regimes. Compile existing site data from the PA program relative to risk assessments and loss from varying flow regimes. For unevaluated resources such as tribally-identified resources that are not archaeological in nature, model quantitatively flow regimes at various stages and map the model results in combination with resource locations and other descriptive parameters. This information would help to determine inundation frequency as well as critical threshold levels for triggering recommendations for remedial responses.

3) Develop tribal monitoring programs for the evaluation of impacts to cultural resources. Tribal programs to monitor and assess cultural resources are an important component of resource assessments as these programs supply different but complementary information on resource impacts. Resources may embody a full range of important qualities. These may include data concerning past occupations as well as tribal histories for descendants of the prehistoric occupants. While archaeological monitors can evaluate the physical impacts of data loss on resources, others may view the resource impacts in other ways. Because of these varying perspectives on resource qualities, resource impacts are viewed differently. These impacts may be related to integrity of the resource, information loss of the resource, and vandalization. For Traditional Cultural Properties (TCPs), resource integrity and loss are defined within the concepts of the group for which they have significance. Rarely can outsiders evaluate these resources using traditional definitions for important resource elements. For these reasons, tribal groups can provide invaluable information concerning resource impacts. This information is complementary to conventional assessments and it helps to provide assessments on the full range of important qualities of the resource.

In addition, consultation with these groups provides information that is important for additional monitoring and research activities that investigate dam related impacts to other resource qualities. There are several ongoing tribal monitoring programs to assess resources impacts under the PA program. These activities monitor and assess previously identified resources several times a year. Under the GCMRC cultural program, tribal monitoring programs would be developed to enhance the monitoring and research activities developed with the AMWG for a broad range of cultural resources including botanical and physical resources. It is recommended that tribes should develop and implement field visits to monitor resources. Monitoring activities should be structured so that they inform tribal values and concerns as well as monitoring and research activities included in the GCMRC cultural program. Also, resource locations and areas of possible impacts from flooding, research activities need to be mapped. These maps will assist in consultation with the tribes and for their monitoring activities. Together, these activities would be an integral part of the long-term monitoring program supported by the GCMRC.

4) Test and apply a model of geomorphic processes relative to archaeological site erosion. The existing work linking certain geomorphic process and archaeological site erosion (Hereford et al. 1991) needs to be evaluated. This work hypothesizes that sediment loss related to certain flow levels fosters arroyo cutting through upper terraces, mainstem bank failure, and cutbank retreat. These processes remove terrace sediments that contain archaeological deposits. Past site assessments from PA program field work, indicates that additional archaeological site monitoring needs to occur to test the above hypothesis.

In addition, sediments recently deposited from the beach/habitat building flow need to be mapped and compared to past deposits and resource locations. This information should provide a basis to determine the possible extent of resources that may be impacted by these large flood episodes. Together, this information should provide data to formulate hypotheses to test the geomorphic model for predictive benefits to both locate additional sites and develop site mitigation strategies to conserve resources.

All of the assessments and activities suggested above provide basic data for describing the existing data on culture resources. These data can be used to formulate research questions that are directed at the relationships between impacts resulting from dam operations and the resource assemblage. These assessments and monitoring activities provide the initial bases for the research related information needs described below.

5) Develop mitigation strategies for the broad spectrum of cultural resources where there are documented dam impacts by monitoring assessments, and 6) Characterize resources through scientific study.

Monitoring activities can indicate that change in resource conditions is occurring. The research activities are formulated to explain the sources of that change as well as characterize the resource. It is proposed that research activities be initiated to determine relationships between resource impacts and "dam operations" when these are suggested from monitoring observations.

In addition, resources can be studied based on research domains developed within the HPP. These domains inform on important aspect s of past occupation within the river corridor. These domains are: dating and chronometrics, demography, subsistence, settlement systems, cultural affiliation, socio-political issues, technology and exchange. These areas provide an intellectual framework to formulate data collection. A full range of methods for data retrieval must be devised. These can include non-invasive techniques such as historical literature searches, traditional oral histories, remote sensing, as well as conventional invasive data recovery efforts. Resources targeted for data recovery should include those in which dam related impacts are suggested although that relationship may not be understood. Other criteria to target resources include the immediacy of the impacts, the probability of data recovery, data utility for other program research /monitoring efforts and resource significance.

In addition, resource significance includes scientific value such as the ability of the resource to inform on the above research domains. Traditional values are also a component of resource significance. These values will depend on the resource and the tribal group that identifies the importance of the resource. In this area, tribal participation in providing monitoring information, devising treatment options, evaluating proposed activities, and conducting appropriate field activities is critical. Data recovery will be structured to answer research questions related to the source of resource impacts and it will be compatible with the research domains listed within the Historic Preservation Plan and developed under the PA programs and new domains yet to be developed, as these organize inquiry and inform on past human use and occupancy of the river corridor.

Without the benefit of results of the above monitoring assessments, specific research endeavors cannot be proposed although some broad considerations have been suggested above. Other general areas of possible research can be suggested based on the preliminary information that is currently available.

Following the above compilation of data related to visitor impacts, research questions may center around the relationship between resource accessibility and visibility and degree of impacts identified. Resource accessibility can include access via established trails, non maintained trails, pedestrian /auto, and river. Visitor impacts may tend to correlate with various flow regimes that allow access to areas such as beaches and trails by recreationists.

In the area of physical impacts to resources, possible research questions include investigations to determine the relationship between bank failure and cutbank retreat, various flow regimes and resource loss through erosion. Other questions center on the ability of high flows to stabilize predam terrace deposits and the cultural resources they contain. Finally, if predam terrace deposits cannot be stabilized and terrace deposits are effected by dam flows, resource documentation should proceed on cultural resources to be lost from the human record as a result of these operations.

Program Implementation

The methods for implementing activities included in this cultural program will follow the established protocols for the GCMRC's work that have been discussed elsewhere. This process is different from the protocols that operate within the PA program where the BOR and NPS remain legally responsible for program implementation. The general process of the GCMRC includes the participatory approach developed within the framework of the AMP, and this approach will be emphasized within this program. The specific methods employed within this program will emphasize collaboratory efforts and Native American involvement. The three program elements (core program, tribal projects, and cooperative programming) emphasize Native American involvement and this will be reflected in the ways in which the program activities are implemented.

A methods criteria will be developed with a team of agency cultural representatives and tribal participants (the team). These criteria will include evaluations based on relatedness to AMWG objectives, degree of tribal involvement at various project levels, cost considerations, work priority within the cultural program, and the ability of the information to relate to other GCMRC programs. The team will assist in the review and recommendations of proposals that are proposed within the cultural program. Because Native Americans often view other resources (e.g., plants, fishes, land forms) as traditionally cultural, proposals from other GCMRC programs will be screened by the program manager to determine if there may be cultural content. Proposals with cultural content will be referred to team members for comment. Specific methods and approaches for proposed projects will not be specified within the methods criteria, but will be defined within the competitive process.

Summary

The monitoring and research activities proposed in this plan are general, given the available data at this time. It is anticipated that this plan will undergo substantial revision as information is assessed and evaluated and there is collaborative participation in defining program objectives.

The program can be summarized to include three elements. These include: 1) the core program that emphasizes the monitoring and research activities necessary to address the objectives and information needs identified with the AMWG; 2) individual tribal projects; 3) and cooperative programming. The cultural program monitoring activities are devised to provide base line data from which to formulate research questions. Research activities will be proposed on the basis of monitoring data. Individual tribal projects will be supported by the cultural program to involve the tribes in program activities. In many instances, tribes are the most appropriate groups to undertake the activity. The program support for these proposals is intended to foster the development of scientific endeavors by the tribes as well as projects that incorporate traditional perspectives and approaches. Cooperative programming involves educational opportunities for tribal students in the programs activities. In addition, public outreach is included in this area. It is anticipated that informational channels will be developed in consultation with the tribes and that they will be actively involved in the information dissemination and interpretation.

The monitoring and research proposals included within this plan are formulated in a step-wise fashion. First, the existing data must be synthesized. Following this the data base will be evaluated relative to impacts to resources. Geomorphic information, resource mapping, and flow regime modeling will be prepared and analyzed to provide additional descriptive data. Data retrieval may be proposed following a complete assessment of the status of the resources and impacts to address research questions. Specific details will be developed after data assessment and in consultation with the cultural program team.

There are several issues that can and will amend this preliminary plan. These include changes in the knowledge base of the cultural resources. This may result from the discovery of new resources within the area, unexpected and/or accelerated impacts to resources, and changing AMWG objectives. All of these issues may result in redefining priorities for the cultural program. However, the method of program implementation will not change. The program will continue to function in a collaborative and participatory manner.

THE SOCIOECONOMIC RESOURCES PROGRAM

The objectives and information needs specified for socio-economic resources are as follows:

- Determine criteria and aspects that are important to or detract from wilderness experience.

- Determine adequate beach quality, character and structure for camping throughout the system.
- Determine if operating criteria maintains safe and adequate power craft navigability in Glen Canyon and upper Lake Mead.
- Determine flow regimes necessary to maintain fish populations of 100,000 adult trout (age class II plus).
- Define pattern of waterfowl and other wildlife use and conflicts to other uses.

There are many socio-economic resources associated with the Grand Canyon riverine environment including recreation (i.e., boating, fishing, hiking, sightseeing), electric power, and water. Further, due to the vastness and geologic distinctiveness of the Grand Canyon, the Park has acquired national and international recognition, including the designation as a World Heritage site by UNESCO, and all of the resources in the Canyon are considered to be significant to the public.

Recreation

Recreation use of the Grand Canyon is of economic and environmental importance. As a major public use within the Canyon, recreation creates jobs and financial support within the region, but also is a significant component of impact to other resources. The preferred alternative in the EIS has considered impacts on recreation and has attempted to enhance the recreational experience (e.g., opportunities to experience wilderness, natural quiet and solitude, etc.) in the Canyon and increase safety. Also of importance are the possible impacts of recreation on Canyon resources. The objectives of the long-term monitoring and research program, therefore, are to determine whether recreation is enhanced and safety improved over impacts resulting from historical dam operations, and whether changes in recreational patterns resulting from selected dam operational conditions have any effect on the Canyon's downstream resources.

To determine whether dam operations are affecting the pattern and amount of recreation use in the Canyon, data on use and changes resulting from recreation will be compiled on two year intervals. Such data can be utilized to assess changes in use, but also may help determine causes of some changes in other resources (e.g., fish populations, cultural resources, and beach sizes or quality, etc.). Recreation use data are available from, or can be obtained through, the NPS, Arizona Game and Fish Department, Native American tribes, and fishing guide, angler and boatman surveys, for rafting, angler, and miscellaneous users. Data for white water rafting (including commercial, private and tribal enterprises) would include user days, length of trip, put-in and take-out points, beaches used, and safety (accident) records. Information on angler uses would include commercial and private use above Lees Ferry relative to angler user days, fish catch data, and safety (accident) records. Miscellaneous uses, such as, bird watching, use of riparian habitats (both mainstem and tributaries) for hiking, sightseeing within the Canyon, etc., would be evaluated through NPS and Hualapai Tribe permitting records, Game and Fish surveys, and other means. Survey results would be summarized and evaluated every two years.

Beach area data will be monitored using aerial video- or photography at the same discharge levels every other year. Changes in beach camping area at high discharge levels, can be determined through digitized video- or aerial photographs and validated on a sample basis through ground truthing coordinated with beach surveys under the sediment dynamics component of the long-term monitoring and research program. Validation of campsite area change can be determined by digitizing the onriver mapping.

To determine possible reasons for changes in recreational use, recreationists' values and concerns would be monitored on a five year basis or following unusual events such as flooding. This information would be gathered via user preference and attitude surveys of appropriate groups. This value determination is separate from values determined using non-use value methodologies. The former deals directly with use and experiences in the Canyon while the latter are based on no direct contact with the Canyon.

Hydropower Supply

Hydropower supply is an integral part of the economy of the region. Changes in power operations resulting from changes in annual dam operations would affect the power supply and its costs. The objectives of this program are to determine the impact of changes in dam operations on hydropower outputs and the concomitant power marketing and economics of the region, a concern of those agencies and organizations associated with hydropower production.

Actual power generation will be monitored on an hourly basis as input to assessing the consequences of dam operations on power economics. Power generation is also a method for estimating water discharge rates and volumes.

Water Resource

Water resource has associated value with both its quantity and quality. Reservoirs present opportunities to regulate market supply. High water levels in reservoirs and rivers also normally maximize recreation benefit and values. High water quality can also create additional value in water supplies. Although operating criteria can effect water quality and therefore realized values, it is less likely to impact water quality.

A comprehensive assessment of both market and non-market costs and values was conducted in Phase II of the GCES. That assessment established an appropriate baseline analysis of Grand Canyon resource values. Also, for the period of study during the 1990s, it established appropriate cost analysis relating to impacts of alternative dam operating criteria.

What has not been accomplished to date is development of an effective Cost/Benefit Analysis (CBA) model that can easily accommodate new economic assessments of any alternative operating criteria proposed for the Dam. A proposed model should accommodate evaluation of all associated market and non-market costs and benefits, including intrinsic and existence values of key resources.

Development of this CBA model should be along design parameters that permit eventual incorporation into a more robust decision support system (dss). Appropriate timing for development of the CBA model should be in year four or five of the first 5 year plan.

INFORMATION TECHNOLOGIES

Extensive data and information currently exists in the GCMRC relating to resource levels, quality, relationship to other resources, etc. Further, potentially equal amounts of data and information exist within museums, universities, agencies, etc. This information represents a valuable resource to researchers, managers and interested stakeholders. Its potential utility for problem solving, formulating improved management guidelines, modeling relationships, or increasing understanding of the various resources and system under study, justify an aggressive program in information technologies.

Prior to conducting the extensive synthesis of these data and information, planning is required to properly enter the information into a computerized Database Management System (DBMS) and Geographical Information System (GIS). Software systems utilized need to have the following general capabilities.

- Accommodate large relational databases.
- Be time and cost efficient and maintained through R&D programs.
- Be compatible with software utilized by stakeholders and scientist groups.
- Be user friendly.

Protocols for Data Collection, Processing and Use

Each component of the Strategic Plan must have an explicit, detailed protocol which spells out: 1) objectives, 2) experimental design, and 3) procedures for data collection, QA/QC, data analysis, data storage, and reporting. This allows anyone to replicate measurements and to evaluate them in a consistent statistical manner. Where appropriate, each experimental design will be evaluated for statistical integrity. The protocol for each component will specify the level of knowledge and training required for those collecting field data, analyzing samples, entering data, and interpreting the data. There will be a comparable protocol for managing the database.

Scientists collecting the data will be involved with data interpretation. Although the time frame of the GCMRC program extends well beyond the participation period of any one scientist, it is anticipated that those who collect the data will be familiar with GCMRC data management protocols and may use the data as part of ongoing research programs. This connection of data collection and interpretation will result in data being collected appropriately and efficiently.

Releasing and sharing data must be a requirement for every project. Those collecting original information, however, should be allowed a reasonable time for analysis and publication before releasing the data to the public. Trust must be established among data collectors and managers to ensure transfer and integration of information. Each monitoring and research project will prepare an annual report using a consistent and defined format, including reports from data base managers.

Database Management

A general principle is that all data will be freely available. However, in some cases, such as archaeological-site data, endangered species data, and data that Indian Tribes define as sensitive, a level of confidentiality will be necessary. Explicit protocols will be developed to ensure confidentiality.

A centralized, integrated database will normally avoid duplication of effort and facilitate exchange of information among projects. However, benefit can also be gained from portions of the system being distributed. Efforts will include incorporation of information from past monitoring, inventories and research. Each file in the database must be cross-referenced to files which document data-collection procedures, variability, and uncertainties. All data would be copied and stored in at least two locations to maximize security.

GIS and Remote Sensing

The use of Geographic Information Systems (GIS) for data storage is an important component of the data management process. Data sources can be referenced and identified in the GIS, but not all data can be put into GIS format. GIS can be an important analytical tool for integrating and comparing spatially based data, but the applicability of this technique will depend upon the particular objectives of each monitoring project. Each project will specify which GIS data layers are required.

The GCES program had significant accomplishment in GIS system development, meta-data protocols and establishment of GIS data reaches for the Canyon. The validity of the existing GIS reaches in the Canyon will be tested for representativeness or designation as critical reaches. Usefulness of these reaches for the GCMRC program will be evaluated against objectives and priorities for long-term monitoring. The use of satellite and remote sensing (e.g., aerial video- and photography) data will also be evaluated relative to the level of detail needed for each monitoring project.

Increasing Stakeholder Direct Access to Data and Information

The hardware and software systems of GCMRC, and the analysts operating these systems are necessary for two primary information technology thrusts planned by the GCMRC. These are:

1. Develop and implement programs for direct access and use of GCMRC data and information.
2. Develop and implement an outreach program for stakeholders and analysts to maximize utilization of developed science information.

Direct Access. Developing direct access to GCMRC databases can be accommodated in several ways, and all methods, as appropriate, will be used. Opportunities exist to utilize the Internet for information dissemination in appropriate situations. In like manner, interested parties can enter program files directly, assuming electives are established. Some access will, of course, be limited, including unpublished data, the location of endangered species and cultural resource information. Protocols will be established to assure that only authorized access is permitted.

Developed Outreach Programs

To also accommodate greater use of GCMRC information will involve significant interaction between GCMRC information technologists and stakeholders. Several programs are planned to insure increased use of GCMRC information as follows.

1. Development of workshops to minimize difficulties in using important GIS software.
2. Involvement of stakeholders and scientists in conceptual modeling workshops to increase knowledge of resource information systems.

3. Training of stakeholders and scientists in use of software such as ARC-VIEW and SAS to enhance utility of archived data.

CHAPTER 7

SCHEDULE AND BUDGET

SCHEDULE

The strategic plan outlined in this document addresses monitoring and research for a five year period: Fiscal Year 1998 - 2002; i.e., October, 1997 - October, 2002. Each year, in April, an Annual Plan will be drafted to guide implementation of specific elements of the Strategic Plan for the following fiscal year. A science plan must be flexible under any circumstance. A science plan developed for an adaptive management and science program assumes significant flexibility as a design parameter. Configuring plans and funding should be specified in each Annual Plan.

This Strategic Plan is designed to guide specified synthesis, monitoring and research in the Grand Canyon National Park and Glen Canyon National Recreational Area through three fundamental science phases. All of the syntheses, monitoring and research previously noted can be captured under the following three phases.

1) Development of conceptual models, synthesis of existing knowledge, and determination of key factors affecting differing resources and their related change.
2) Definition of integrated impacts of key factors within a resource set and across all resources (ecosystems).

3) Development of decision support guidelines and models to assist managers and interested stakeholders to better understand resource interactions, impacts of dam operations on resources, and procedures for mitigating impacts.

Figure 7.1 graphically provides general targets for the scheduled completion of the three general phases of the five-year Strategic Plan.

Phase 1

This phase is critical in realizing two major outcomes. First, a conceptual model of the riverine system is needed to define most critical intra- and inter-resource and process linkages and interactions. Development of this conceptual system model will rely on existing knowledge of current and past science investigators, using a quasi-Delphi process and simulation modeling exercises after Hollings (1978), and Walters (1986). Development of the conceptual model will occur in the first year of Phase 1 immediately after completion of this step. While intensive information synthesis is occurring, invited scientists and technologists will be led by the GCMRC to develop ecosystem study methodology to assure assessment and interpretation of integrated relationships of resources and resource attributes. Associated scientist workshops will focus on evaluating and developing state-of-the-art protocol, procedure and technology to enhance all measurements.

Second, extensive data and science have been completed on Colorado River resource changes since dam construction. A complete synthesis of these data and studies will be completed in Years 1 and 2. Included in these assessments will be a synthesis of all past research on Lake Powell, especially data collected from 1989-1996, to determine if operating

Final

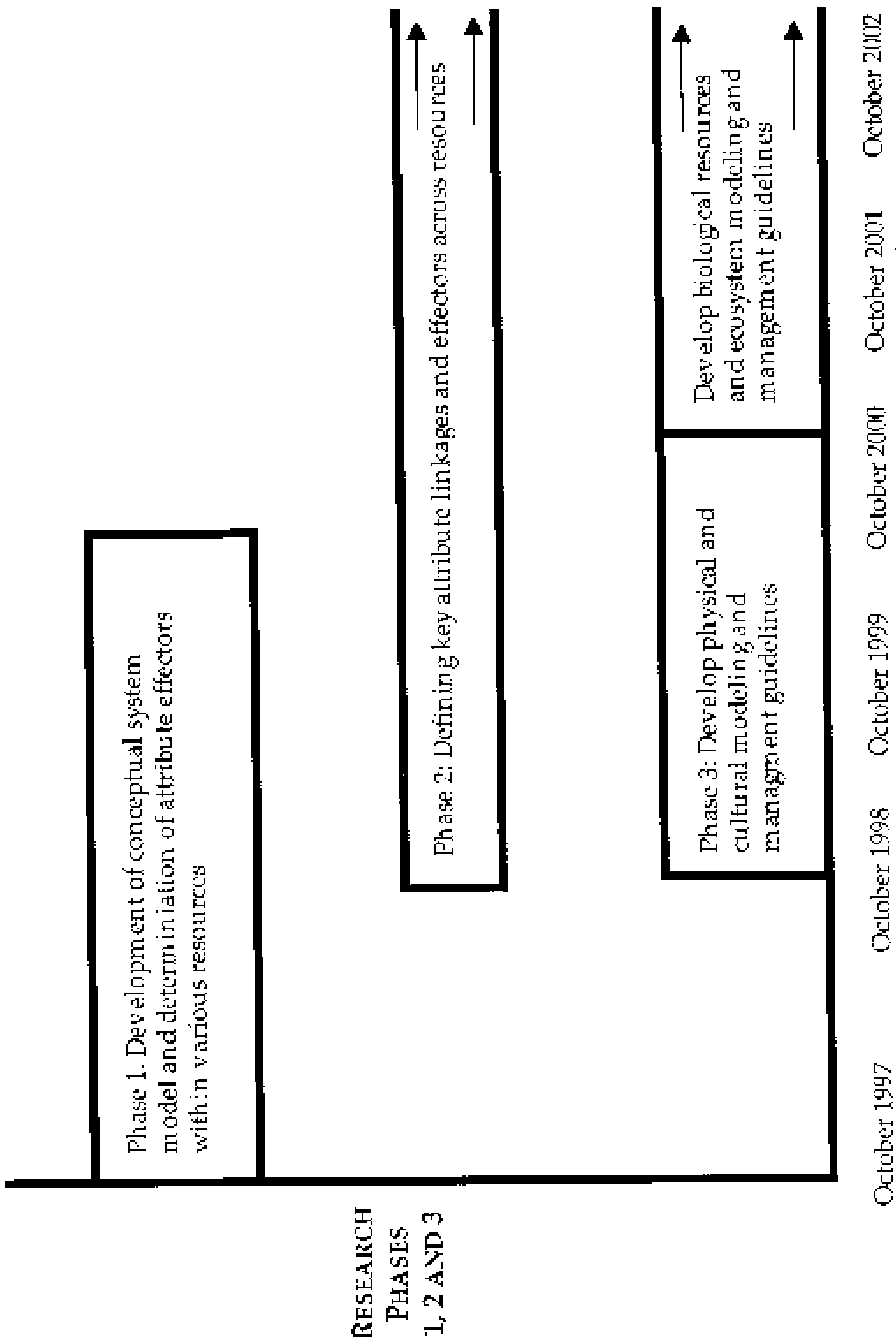

Figure 7.1 Timelines for completion of major phase years in Strategic Plan

criteria under the ROD are likely to effect physical, chemical, or biological resources in Lake Powell. In addition to the above synthesis, there will be a more limited assessment of research and data on Colorado River resources prior to dam construction. These syntheses of baseline conditions are critical in understanding resource impacts due to current dam operations.

The primary goal of all the above syntheses will be to identify key driving resource variables or attributes associated with change in individual resources that are directly related to dam operations. Where possible, linkages of key driving attributes across resources will also be determined.

Interim monitoring and research activities in Years 1 and 2 will be related to specific stakeholder objectives and information needs. These interim research and monitoring activities may undergo substantial revision following the development of the conceptual model and completion of synthesis activities.

This Strategic Plan, which is based on best available knowledge, as was the GCDEIS, can be greatly improved over the next two years as information is derived state-of-the-science assessments. An intensive review of the Strategic Plan will be conducted after Phase 1 is completed to enhance the plan.

Phase 2

This phase will be used to monitor driving attributes determined for individual resources, but will be primarily focused on defining driving attributes that operate across resources. Selected research programs will be necessary where suitable data is insufficient to define relationships.

Phase 2 is open-ended at Year 5, because all programs will not be completed in the first 5-year Strategic Plan. The resource area of greatest complexity and likely to have the longest cycle for defining attribute interdependence is biological resources. These relationships are not anticipated to be defined to a satisfactory level until the second 5-year plan.

Phase 3

This phase is the most critical phase for realizing maximum benefit to managers/ stakeholders. In this phase, established scientific relationships within resources can be used to develop decision rules, management guidelines, and decision support models and systems. Sufficient information exists to begin Phase 3 in FY 1999 in physical resources. Cultural resource modeling will likely begin in FY1999 or 2000. This phase, by necessity, will extend into the second 5 year plan, due to the inability to effectively model many biological resource interactions. Phase 2 analyses of these resources will not have progressed sufficiently to develop all significant biological relationships into algorithmic form.

BUDGET

The budget process for funding the GCMRC involves a transfer of funds from the Western Area Power Authority (WAPA), a federal government entity, through the Bureau of Reclamation, to the GCMRC, an administrative unit of the Office of the Secretary, United States Department of Interior. This budget is for the entire Adaptive Management Program (AMP) called for under the Grand Canyon Protection Act. To accommodate the transfer, the Upper Colorado Region of the

Bureau of Reclamation, Salt Lake City, facilitates the Adaptive Management Program and is the budget office for the GCMRC.

The budget for the original Bureau of Reclamation GCES program increased from less than $1 million per year in 1982 to over $10 million per year in the early 1990's. The 1996 budget was approximately $7.0 million.

The fiscal year 1997 budget for the Adaptive Management Program is approximately $7.0 million. It is anticipated that the FY98 and FY99 budgets for the program, already in planning, will also approximate $7.0 million

Although some opportunity does exist for budget enhancement during the five year planning period (1997 - 2002), the Adaptive Management Program and GCMRC are planned around an average annual budget of $7.0 million. The first budget that can be significantly influenced by the new research center is FY2000. A proposal for an increased allocation, in FY2000 will center around equipment for implementation of more automated monitoring systems for the Grand Canyon National Park and Glen Canyon National Recreation Area research programs.

Of the total $7.0 million per year budget allocation approximately $5.0 million is placed into on-the-ground research programs. Approximately $0.5 million is required by the Upper Colorado Region, BOR to administer the Adaptive Management Program, and $1.2 million is required to operate all of the GCMRC's administrative programming.

The Adaptive Management Program is comprised of four primary entities (Figure 7.2), all funded out of the $7.0 million annual allocation. The Upper Colorado Regional Office of BOR

(Salt Lake City) administers the AMP for the Secretary. This involves services provided to the Secretary's designee, the Adaptive Management Work Group (AMWG), the Technical Work Group (TWG) and the GCMRC.

The BOR, for example, provides all administrative services for all meetings called by the Secretary's designee, especially those of the AMWG and TWG. This can involve payment of members travel expenses, fees for meeting rooms, speakers, etc. The BOR also provides direct services to the GCMRC, including personnel, budgeting, contracting, purchasing, etc. Since the GCMRC is not an official entity of BOR, these services are purchased at competitive prices with similar services available from other agencies.

The GCMRC staff provides administrative, management, technical, scientific, service and other support to the research program under its direction. In general, the monitoring and research programs will service approximately 25-40 separate research contracts and/or cooperative agreements each year. Approximately $1.5 million is required to service programs which involve other federal and state agencies, Native American Tribes, consulting firms, etc. Within external to research contracts the GCMRC provides logistics, surveying, GIS and data management support. For example, logistics support for all GCMRC supported research trips through the Grand Canyon each year costs approximately $500,000.

The above annual budget levels noted for the GCMRC's five year Strategic Plan is only for program requirements in which the center is currently active and for which the center is currently responsible. Although this does include activities on the biological opinion (T&E species) and programmatic agreement (cultural resources), it does not incorporate other potential program areas currently in development. For example, long-term monitoring and research programs for Lake Powell are not incorporated in the plan or budget. In like manner, monitoring and research programs required to evaluate impacts of flash boards or operation of selective withdrawal structures on Glen Canyon Dam are not programmed into the budget specified.

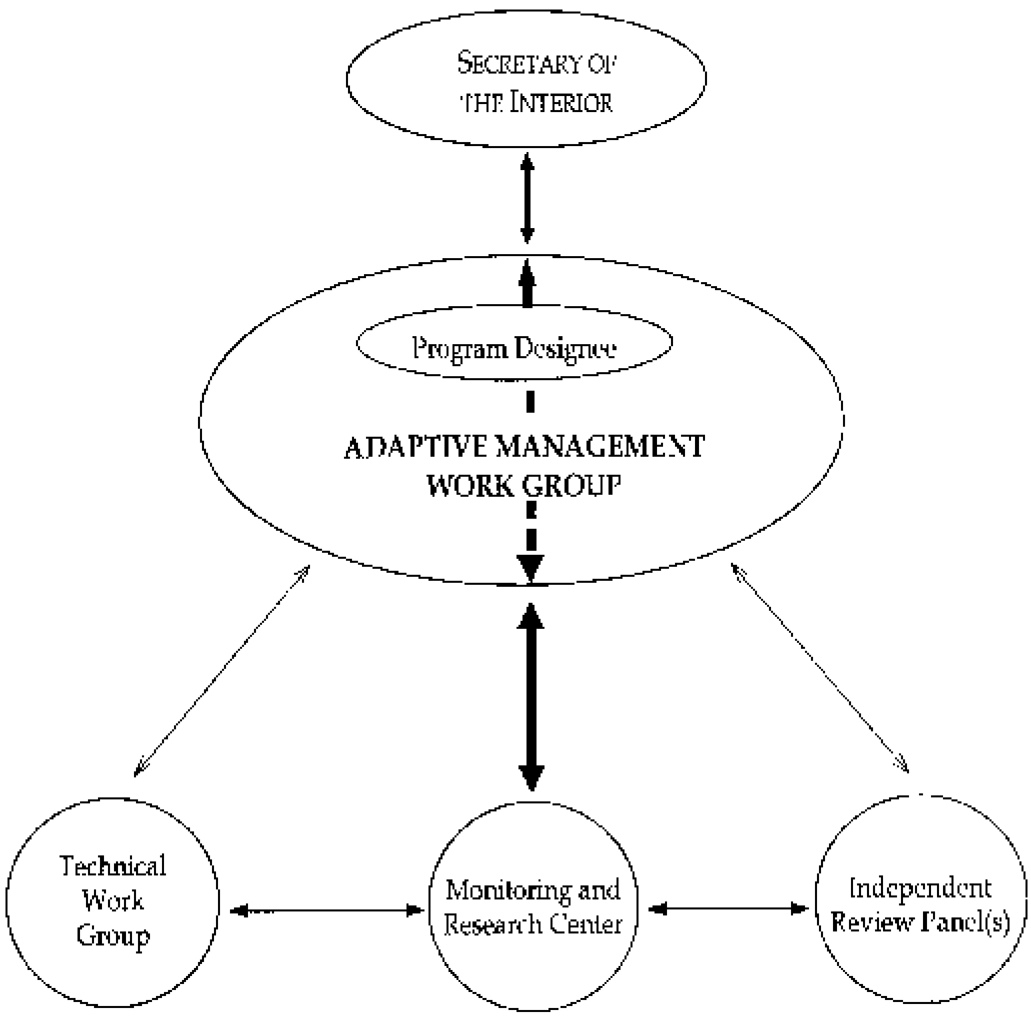

Figure 7.2. Adaptive Management Program for the Grand Canyon Monitoring and Research Center.

Monitoring and Research Planning
WATER RESOURCES #1

<table>
<tr><th>Stakeholders' Objectives</th><th>Stakeholders' Information Needs</th><th>Scientists' Knowledge</th><th>Scientists' Need To Know</th><th>Scientists' Monitoring Statements</th><th>Scientists' Research Questions</th></tr>
<tr><td colspan="6">General Goal: The Secretary Shall operate Glen Canyon Dam in a manner fully consistent with the preferred alternative and subject to the Grand Canyon Protection Act of 1992, the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, and the provisions of the Colorado River Storage Project Act of 1956, and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin.</td></tr>
<tr><td>Maintain chemical and physical characteristics of water at levels appropriate to support physical, biotic, and human resource needs of various ecosystems.</td><td>Determine changes in the physical and chemical characteristics over time.

Determine concentrations of chemical constituents in comparison with established EPA/state standards.</td><td>Canyon water characteristics are a function of Lake Powell water.

Lake Powell water release characteristics are a function of dam operations and they are variable over time.

Conductance at several sites in the Canyon is known.

Past daily average discharge are known for:
• Lees Ferry
• Grand Canyon
• Paria
• LCR-Cameron

Discharge routing model exists that predicts discharges to 45,000 cfs in all canyon reaches.</td><td>Ability to predict downstream water temperatures in mainstem and back water from dam release on basis of season and stage.

Influence of flow variables on aquatic biota, especially temperature and sediment.

Long-term phosphorus changes are not known and not predictable.

Levels of phosphorus, nitrogen and salinity for comparisons to standards.

Interactive relationship between tributaries and springs and mainstem water temperature.

Physical and chemical water trends, such as salinity, relative to dam operations.</td><td>Monitoring temperature through canyon corridor.

Monitor water temperature to determine aquatic productivity.

Monitor dissolved nutrient changes from dam to Lees Ferry.

Monitor nitrogen and phosphorus levels in stored sediment and sediment being deposited.

Determine appropriate water quality standards & evaluate water quality against established standards.

Monitor bacteria levels.

Monitor unit values of stage and maintain stage discharge relations at:
• Lees Ferry
• above LCR
• Grand Canyon
• Diamond Creek
• Paria</td><td>Determine effect of dam discharge on temperature.

Determine and model longitudinal rate of water temperatures increase throughout the canyon.

Determine the relationship between flow and temperature.

Determine temperature variation in backwaters.

Determine changes in phosphorus salinity levels and their association to dam operations.

Determine Lake Powell water quality changes due to dam operations.

How do reach average water velocity at very low flows affect the accuracy of the discharge routine model?</td></tr>
</table>

Monitoring and Research Planning
WATER RESOURCES #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
		Hourly dam releases completed from power generation data are available. Reach average water particle velocity at steady 15,000 and 45,000 cfs and unsteady releases with daily mean of 15,000 cfs. Know average water particle velocity in Glen Canyon reach at steady 5,000 cfs. Past stage at 30-50 sties for various releases regimes. Some information on flow from ungaged springs.	Relationship of dam operations to bacterial levels, especially MLIS. Effects of variability in water quality in Lake Powell to forebay/discharge quality. Unit values (15 min. values) of discharge at: Lees Ferry, above LCR, Grand Canyon, Diamond Creek, lower LCR reach, Paria. Reach average water velocity at low flows. Frequency of flooding from ephemeral tributaries (important for aquatic food base modeling). Ability to calculate stage at a given location and time. (Model needs to be widely available).	Monitor stage and discharge at base flow below Blue Springs area for temperature, discharge, and chemical, physical characteristics to mainstem T&E species. Monitor unit values of stage and discharge in LCR near Cameron. Hourly hydrograph of lower LCR (Cameron gauge is of limited value to fisheries biologists). Monitor base flow discharge on • Diamond Creek • above Kanab Creek • Havasu Creek • possibly Spencer Creek for T&E species. Use event recorders (e.g., daily camera) monitor flows at the mouths of the four large tributaries (Paria, LCR, Kanab Creek, Havasu). Fisheries need.	Contingency plans for rapid study of unpredictable events (floods, debris flows, fish kills, exception releases, etc.)

Monitoring and Research Planning
SEDIMENT RESOURCES #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
1. The overall resource management target is to maintain a range of sediment deposits over the long-term, including an annually flooded bare sediment (unvegetated) active zone, a less frequently flooded vegetated zone, terraces (within the 45,000 cfs river stage), and backwater channels. The goal of managing sediment resources will be on a reach scale basis. Should significant and localized adverse impacts occur, site specific mitigation would be considered along with possible modifications to dam operations.					
As a minimum for each, maintain the number and average size of sandbars between the stages associated with flows of 8,000 and 45,000 cfs and the number and average size of backwaters at 8,000 cfs that existed during baseline conditions.	Characterize sandbar, backwaters, and return channels target structures. Determine changes in sediment storage and define balances and hydraulic processes necessary to maintain target sandbar levels. Evaluate historical sandbar change. Develop methods for predefining change in sandbar character structure under alternative dam operating criteria. Determine a baseline.	Enough sediment exists in the system under current regime to match sandbar formation under interim flows, but insufficient sediment exists for regimes of the 1880s. Data base exists for sandbar changes during post dam operations. Can predict amount and area distribution of sand deposition from tributaries in mainstem channel and sandbars. Sand channel monitoring sediment transportation modeling accurately monitor sand in channel.	Where sand in the Glen Canyon reach comes from. Monitor number, size and morphology of sandbars and backwaters at various flow regimes. Synthesize and evaluate sand bar data from mid 1970s to present.	Monitor flow and sediment input from the Paria and LCR tributaries. Establish observer system to monitor occurrence and size of debris flows. Monitor sand stored in the channel bed and sandbars in the Glen Canyon, Marble Canyon, and Grand Canyon reaches. Monitor sand in sand pools below main side streams (i.e., LCR). Monitor physical occurrence of backwaters and shallow channel side waters suitable for young fish, including HBC fishery needs.	Analyze historic debris flows and their effect on the ecology of the riverine system under low flow regimes. Estimate sediment contributions from ungaged tributaries by debris flows. Complete the development of debris flow prediction techniques. Determine if current monitoring methods & networks for sandbars and channel bed sand should be modified to provide better correspondence between channel stored sand and sandbars. Investigate methods for determination of depth to nonerodible material in the channel. Map the channel geometry in any reaches where bed evolution predictions are needed. If needed to improve accuracy of the discharge & sediment routing models, measure reach averaged flow velocity at low flow. Test models currently being developed with data from the spring 1996 high releases & other available data to verify predictions of rates and amount and areal distribution of bed evolution. Use well tested multi dimensional bed evolution models to investigate the relation between the amount of sand available and size, duration of habitat building releases required to rebuild sandbars & backwaters of given size and character.

Monitoring and Research Planning
SEDIMENT RESOURCES #2

Increase the average size of sandbars above the 20,000 cfs river stage and number of backwaters at 8,000 cfs to the amount measured after the 1996 test of the beach/habitat building flow in as many years as reservoir and downstream conditions allow.	Define target backwater ecosystems and associated flow regimes. Define historical variation in backwater number and character. Determine changes in backwater character and structure associated with dam operating criteria. Define all linkages, associ ations, interdependencies, etc.; of physical backwater resources to biotic entities. Define processes neces sary to maintain back waters at target levels.	Know long-term changes in sand storage at Lees Ferry near Grand Canyon. Shorter term changes known at several locations.	Long-term trends in variability in sand storage. Accuracy of model predicted rates of erosion and sand deposition.	Monitor sediment movement through system with model verified by cross sections. Monitor physical and temporal characteristics of sandbars (location area, volume, stability, etc.)	
Maintain system dynamics and disturbance by redistributing sand stored in the river channel and eddies to areas inundated by river flows up to 45,000 cfs in as many years as possible when downstream resources warrant and when Lake Powell water storage is high.	Define character and structure of all sandbars and backwaters in system after 1996 test flows. Develop methodologies to define future operating alternatives to maximize benefit to sandbar and backwater character and structure.		Continued monitoring required to know changes & status of system. Rate of change of sand bars & backwaters during major deposition events. Optimum size & duration of releases to rebuild sandbars & reform recirculation zones for mainstem storage.	Measure and monitor suspended sediments at Lees Ferry at peak flow events.	
Maintain a long-term balance of river stored sand to support maintenance flow (in years of low reservoir storage), beach/habitat building flow (in years of high reservoir storage), and unscheduled flood flows.	Define historical & current levels of bottom sediment deposits in system. Define minimal levels of bottom sediments necessary to maintain long-term sandbar, backwater, channel sediment deposits. Develop procedures to monitor & predict impacts of alternative operating criteria on channel sediment deposits, & implication to sandbars and backwaters in selected reaches.	Sediment transport relationships are known.	Amounts of stored sedi ments in river bottom. Minimum levels of stored sand required to maintain sand resources at target levels. Accuracy of bed evolution models to predict sand transport bed evolution. Ability to predict rapid erosion during high releases. Depth of river bed & channel geometry at various locations.	Monitor sediment movement through system with model verified by cross sections.	

Maintain system dynamics and disturbance by annually (in years which Lake Powell water storage is low) redistributing sand stored in the river channel and eddies to areas, inundated by river flows between 20,000 and 30,000 cfs.		Geomorphic/sandbar indicators and cross section indicators can be used to determine when there is enough sand for a flood. Have tools to "predict" backwater formation re: discharge events	Do low flow velocities affect accuracy of discharge sediment routing models. Sediment balance for entire or parts of system. Modeling approach to predict sediment balance, distribution, etc.; by reach.	Monitoring side canyon debris flows.	Investigate the significance of rapid erosion events and, if significant, develop methods for their perdition.

NRC Concerns

1. Development of alternative sampling methods within the National Park.
2. More emphasis on sediment quality.

Monitoring and Research Plan
CULTURAL RESOURCES #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Preserve in situ all the downstream cultural resources and take into account Native American cultural resources concerns in Colorado River corridor.	Develop data and monitoring systems to assess impacts to cultural resources. Develop predictive model of geomorphic processes related to archaeological site erosion including: • Types of degradation; threats • Rates of degradation • Define immediacy of threats to resources • Protection methodologies • Protection, monitoring and research costs. Develop tribal monitoring programs for the evaluation of impacts to cultural resources. • Identification and evaluation of tribal cultural resources • Management recommendations for tribal cultural resources Assess potential affects from various flow regimes on cultural resources.	Locations of cultural resource sites identified in resource inventories. Conditions of sites within various impact zones based on annual monitoring activities. Definition of cultural resources varies by tribe and this information is managed by the tribes. Archaeological sites defined as TCPs by tribes. Paleoindian and archaic sites.	Area assessments, and probability model for location of additional sites is needed. Resources of cultural importance to the tribes.	Assess existing data on isolated occurrences to determine adequacy of monitoring information. Assemble data on resources of cultural importance to the tribes through the development of a GIS program to assist with monitoring programs.	Study isolated occurrences to determine their relationship to site formation or degradation processes and their representation of indigenous use of the cultural landscape. Incorporate traditional histories with archaeological data to understand and interpret human occupation along river corridor. Study methods to identify traditional use areas outside traditional site definitions (e.g. agricultural fields). Design investigations to determine if certain temporal activity / occupation periods are obscured from archaeological record due to dam operations.

Monitoring and Research Plan
CULTURAL RESOURCES #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
If in situ preservation is not possible, design mitigative strategies that integrate the full consideration of the values of all concerned tribes with scientific approach.	Characterize through scientific study and data development all historical and current values of resources to Tribal Nations and to general public. Develop data systems to assess variable risk of damage/loss of differing resources/sites from dam operating criteria. Evaluate flood terrace stability necessary to maintain cultural resources and terraces at pre-dam conditions. Develop mitigation strategies and costs that incorporate scientific and tribal values related to documented site impacts and monitoring assessments. Evaluate effectiveness of monitoring procedures to determine predictive thresholds to indicate when cultural resources become threatened.	Geomorphology processes that promote erosion. Some site stabilization techniques are known.	Factors governing rates of erosion need to be determined. Evaluate effectiveness and need for additional site stabilization techniques. Effects on terract erosion of dam operations versus erosional process that are unrelated to dam operations.	Monitor effectiveness of stabilization techniques. Monitor and evaluate the effectiveness of high flows as a stabilization technique. Monitor terrace erosion.	Define long-term impacts of flows on streamside bank degradation (lateral bank retreat), arroyo headwall damage and model impacts to cultural resources and stabilization potentials. Determine erosional rates operating on cultural resources. Evaluate the past information from data recovery techniques on human occupation and its ability to inform on future mitigative technologies and methodologies. Formulate pilot assessment of geologic history of terrace formations and their relation to past human occupations.

For participating Native American tribes, protect and provide physical access to cultural resource properties for religious purposes within the river corridor	Characterize historic and current religious associations of all sites/locations associated with impacts of dam operations within the river corridor. Develop tribal monitoring for evaluation of impacts to cultural resources including sacred sites.	Location of some traditional cultural sites is known by tribes; some are not yet recorded.	Location of tribe-identified traditional cultural sites needed if individuals will divulge locations. Develop baseline cultural resource maps to facilitate tribal consultation for: • resource locations • risk of loss • resource study locations (including other resource studies) • plant & biological resource locations • sensitive physical/ landform locations	Revise GIS resource maps as needed. Develop effective communication between monitoring programs in other resource programs with tribal monitoring programs.	Define seasons or other specific periods in which access and use are more paramount to Tribal groups than other periods.

Monitoring and Research Plan

CULTURAL RESOURCES #3

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Develop, appropriate research strategies which maximize data collection from mitigation and monitoring efforts for understanding human use and occupation in the canyon.	Characterize all cultural resource sites as to the specific associated management/research needs, i.e., preservation stabilization, documentation, etc., under alternate operating criteria. Design and develop integrated relational data systems to support management and research program goals/designs. Develop technology/ procedures for providing relevant/protected data to appropriate groups/tribes. Ensure confidentiality of data regarding location of cultural sites and ethnographic information.		Site formation processes of deposits not known. Archaeological research questions and their re-evaluation based on future research. Tribal research interests and questions and their articulation with archaeological research questions.		Formulate research design to study the relationship of isolated occurrences to site formation or degradation processes and dam operations. Evaluate specific locations to obtain site formation data for differing temporal occupation/activity periods. Establish and refine appropriate research designs to guide data collection and recovery, and contribute to an improved understanding of the human occupation and use of Glen and Grand Canyons.

NRC Concerns

1. Tribal studies should not be considered academic studies but rather applied studies focused toward specific objectives, that is, the protection of specific tribal cultural resources.
2. Develop a clear outline of criteria to be used in the selection of sites to be monitored.

Cultural Resource

The requirements specified in the Programmatic Agreement are the legal requirements of the Bureau of Reclamation and the National Park Service under Sections 106 and 110 of the National Historic Preservation Act of 1966, as amended. The long-term monitoring and research plan on the Grand Canyon Monitoring and Research Center represents a separate but complementary program with many similar activities although the purpose and scope of the programs are different. The elements of these programs are listed below.

Programmatic Agreement Program

1. Within three months of the execution of the Programmatic Agreement, BOR and the NPS, in consultation with the SHPO and Tribes, shall develop a plan for monitoring the effects of the Glen Canyon Dam operations on historic properties with the APE and for carrying out remedial actions to address the effects of ongoing damage to historic properties. Reclamation shall submit a draft of the Plan to the parties in this agreement for review and comment. Each party shall have 60 days from receipt of the Plan to comment.
2. Remedial measures shall be implemented to mitigate ongoing adverse effects and may include, but not be limited necessarily to, bank stabilization, check dam construction and data recovery, as appropriate.
3. Reclamation and the NPS shall incorporate the results of the identification, evaluation, and monitoring and remedial action efforts into a Historic Preservation Plan (HPP) for the long-term management of the Grand Canyon River Corridor District and any other historic properties within the APE.
4. The HPP shall establish consultation and coordination procedures, long term monitoring and mitigation strategies, management mechanisms and goals for long term management of historic properties with the APE.
5. Reclamation and the NPS shall take into consideration all comments received in their development of a final draft HPP, and submit the final draft HPP to the reviewing parties for a second review opportunity.

GCMRC Cultural Program

1. Core Program consists of monitoring and research activities to address stakeholder objectives and information needs.

2. Individual Tribal Projects to conduct activities related to this program.
3. Cooperative Projects to address education and outreach.

The GCMRC program will address cultural resource issues in an integrated manner with the programs in biological and physical areas through the incorporation of tribal perspectives on cultural resources.

Monitoring and Research

AQUATIC FOOD BASE #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Maintain and enhance the aquatic food base in Glen and Grand Canyon. Maintain continuously inundated areas to Cladophora and aquatic invertebrates at or above 5,000 cfs discharge Aquatic food base data needed for Grand Canyon beyond Glen Canyon.	FOOD BASE CHARACTER & STRUCTURE Define current and historic food base character and structure. Define food base character, structure and requirements for maintaining target populations. Define the species composition and the distribution of aquatic algae & macrophytes in Glen and Grand Canyons.	FOOD BASE CHARACTER & STRUCTURE Food web energetics conceptual model. Mainstem algae & macroinvert community structure, biomass, & seasonal variability; limited similar information for LCR & other tributaries. Linkages between algae and primary consumers & detrital links; diatoms are key organic drift component. Know diet linkages of primary and secondary consumers. Aquatic conversion to energy levels in mainstem.	FOOD BASE CHARACTER & STRUCTURE The community structure interactions among algal species. Phosphorus availability/ limitations. How changes in nutrient regimes in Lake Powell change macrophyte communities. EFFECTS AT TRIBUTARY INPUTS ON NUTRIENT LEVELS Nutrient levels in side channels needed.	FOOD BASE CHARACTER & STRUCTURE Monitor food availability and fish food habits via drift and benthos assessments Monitor the species composition and distribution of aquatic algae and macrophytes in Glen and Grand Canyon. Monitor species composition and density of macroinvertebrates in Glen and Grand Canyons and tributaries.	FOOD BASE CHARACTER & STRUCTURE Complete Colorado River energetics model to determine if the system is nutrient and/or food limited. What factors affect sexual reproduction of Cladophora? What is the microbial contribution to organic processing? Need to inventory aquatic macroinvertebrate community. Fontanalis and Chara contributions to ecosystems.
	EFFECTS OF CHANGES IN DAM OPERATIONS Have these occur at same level going acro Determine system changes to maintain/enhance food base. Define impacts of alternative operating criteria, including thermal modification and low steady flows associated with native fish releases, on aquatic food base. Define the species composition and density of macroinvertebrates in Glen and Grand Canyons. Determine what thermal modification will do. Determine if changes in the CR are due to dam operations or some other changes in the system not related to dam operations.	Physical hard substrate (structural) habitat requirements for Cladophora. Cladophora & Chara are best substrate for diatoms; diatoms are at base of rainbow trout food chain. Photosynthetically Available Radiation (PAR) Model (Yard) relates suspended sediment to PAR Structures known through corridor by seasons. Know diet of rainbow trout in Lees Ferry reach. Have limited information on diet of juvenile native fishes in LCR & mainstem backwater habitats. Have limited information on diet of adult humpback chub from mainstem in Grand Canyon.	EFFECTS OF CHANGES IN DAM OPERATIONS Water velocity, stage, & discharge limits for diatoms, Cladophora, & aquatic macrophytes & macroinvertebrates. How does stage relate to proportion of algae exposed. The potential productivity (food base) loss at differing flows. How does state relate to primary productivity (light, etc.). Determine quantitative estimate of benthic and drifting macro invertebrates in Marble and Grand Canyons. What are links between benthic biomass/ productivity & how does temperature affect benthic communities & primary production. How stage affects diatom abundance distribution. What aquatic plant community changes might be expected as a result of changes in water temperature resulting from selective withdrawal or seasonally adjusted steady flows.	EFFECTS OF CHANGE IN DAM OPERATIONS Monitor aquatic food base in tributaries to determine if changes in the Colorado River are due to dam operations or to landscape changes in the watershed. Monitor productivity, area, and standing crop of attached aquatic vegetation and associated invertebrates above Lees Ferry to distinguish between effects of dam operation and natural variation.	EFFECTS OF CHANGES IN DAM OPERATIONS Determine, in association with specific water releases (defined flows), the effects of flow rate (velocities) on primary producers in the Glen Canyon reach. Determine potential for invasion of other aquatic species, especially under low steady flows or selected temperature withdrawals; zebra mussels, fish parasites, etc.

Monitoring and Research

AQUATIC FOOD BASE #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
		EFFECTS OF CHANGES IN DAM OPERATIONS Know thresholds (temperature/water) of exposure for diatoms, Cladophora. Know colonization and recovery rates of diatom and macrophytes. Nutrient linkages (including ground water & tributary inputs) to primary producers.	Linkages between discharge/aquatic invertebrates/fish. Fontinalis and Chara contributions to ecosystems The interactions among algal species? Taxonomy of river and tributary invertebrates needs to be defined. Nutrient linkages (including ground water 7 tributary inputs) to primary producers. Are allochonous food inputs from arroyo flooding (animal and vegetable material) quantitatively significant food sources? Aquatic food base data needed for Grand Canyon beyond Glen Canyon. What factors affect sexual reproduction of Cladophora? What is the microbial contribution to organic processing? Inventory needs- Oligochaetes, flatworms, chironomids. The potential productivity (food base) loss at differing flows. Interactions of native fish and food base.		

Monitoring and Research Planning
FISH AND AQUATIC RESOURCES
HBC#1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Maintain or enhance the existing population of humpback chub at or above 1987 levels determined by April/May Loop-net monitoring in the lower 1,200 meter of the LCR. (Focused on fish greater than 200 MM, and should include fish health assessment.) Maintain levels of recruitment of humpback chub in the mainstem and Little Colorado River, as indexed by size frequency distributions and presence and strength at year-classes. (Focused at young of year and juvenile fish, and should include a fish health assessment.) Verify the status of and manage for healthy, self sustaining populations of native fish in Glen Canyon based upon the capability of the habitat to support those fishes.	Determine adult humpback chub population levels and evaluate population level trends. Determine levels of recruitment of humpback chub in the mainstem and the LCR Determine quantity & quality of chub backwater and nearshore habitat in mainstem. Develop a backwater quality index, using existing data for humpback chub. Determine and identify surrogate native or non-native fishes for evaluation of health factors for humpback chub. Evaluate impacts of sampling wetlands and recreation use on native fish population	Grand Canyon is one of six populations of humpback chub nationally; it is largest, centered at Little Colorado River (LCR) with successful reproduction in the LCR Possible downward trend in LCR adult numbers over last 10 years derived from mark-recapture data; similar downward tend in mainstem population not noted. Structure and location of nine existing aggregations of humpback chub in mainstem. Site fidelity in humpback chub. Growth and survival of young chub into the spawning population (recruitment) is probably a weak link in maintaining and enhancing the adult population and is low in the mainstem CR. Spates and late summer runoff in the LCR transport young chub into the mainstem CR where their survival is likely lower than in the LCR. Growth and survival of young chub in the cold mainstem CR water is much lower than in the warmer LCR. Young HBC use backwaters and other near shore low velocity habitats in the Colorado River as nursery and rearing areas.	Recruitment of humpback chub into Little Colorado River and Colorado River aggregations What proportion of adult humpback chub in the LCR are resident and what proportion move between the LCR and the mainstem CR PIT tag mark and recapture information for all species marked, (i.e. GCMRC monitored data repository). Genetics of humpback chub aggregations. Ecology information (diet, cycles, requirements) for HBC. Food availability for humpback chub throughout Little Colorado River. Stomach contents analysis of pre-dam humpback chub from existing collections. Non-lethal disease assessment procedures; or assessment procedures for surrogate species Is there successful recruitment of HBC at locations other than the LCR. Effects of sampling efforts on fish populations. How large does YOY HBC need to be to enjoy high survivorship to age 1?	Monitor humpback chubs in the LCR, mainstem CR, especially where population of interest are located. Monitor adult humpback chub population levels and evaluate population level trends. Monitor size frequency distributions, presence, strength, and health status of year-classes. Information needs focus on young-of-year and juvenile fish. Monitor recruitment into the adult humpback chub spawning population in the LCR and other known aggregations.	Evaluate food habits (gut contents) of HBC. Genetically characterize HBC and other native fish aggregations in the LCR, 30 mile, & Middle Granite Reach. Collect HBC tissue samples throughout canyon, extract DNA and bank for future studies. Test alternative methods for tagging HBC smaller than 150 mm. .1.3 Determine most efficient population estimation techniques for HBC. .1.14 Develop life tables for HBC. Determine cumulative effect of handling (research) on fish (stress, trap avoidance, etc.). Is collection and cryopreservation of sperm and eggs a useful approach to conserve and protect genetic resource? Resource competition between HBC and non-native species for drift feed. Evidence of Colorado River spawning.

Monitoring and Research Planning
FISH AND AQUATIC RESOURCES
HBC#2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
		Some adult HBC appear to reside in the LCR while other individuals move between the mainstem CR and the LCR. Aggregations of HBC in the mainstem CR are comprised of large adults with few juvenile fishes. The HBC is a long-lived (> 20 years). Swimming ability of juvenile humpback chub and flannelmouth sucker. Humpback chub and rainbow trout use similar drift feed. Humpback chub seem to feed more on terrestrial than benthic components in lower canyon reaches. Young-of-year HBC (~30 mm) have been collected at a few scattered locations along the mainstem. Have some conceptual "diagrams" of ecosystems requirement. Some fish habitat requirements, i.e.; humpback chub from LCR studies.	Spawning and rearing temperature, salinity, DO requires of humpback chub. Which springs they feed near. (?)		

Monitoring and Research Planning

FISH AND AQUATIC RESOURCES

HBC#3

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Establish a second, self sustaining population of humpback chub by 2005 contingent on feasibility. Monitor for and determine the contribution of other existing spawning aggregations as one component of assessing feasibility.	Develop criteria for self sustaining populations of humpback chubs. Assess feasibility of second population including other current aggregations.	See HBC#1. Most critical criteria for establishing a second population.	Characteristics of candidate Colorado River areas and/or tributaries for establishment of a second breeding population.		Establish experimental populations of special status fishes for physiological studies, including temperature effects on larval fish and for potential brood stock. Evaluate the establishment of an experimental fish breeding program for mainstem reestablishment.

Monitoring and Research Planning
FISH AND AQUATIC RESOURCES
Other Native Fish #1

Stakeholder's Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Verify the status of and manage for healthy, self sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the mainstem Colorado River in Grand Canyon and its tributaries. Verify the status of and manage for healthy, self sustaining populations of native fish in Glen Canyon based upon the capability of the habitat to support those fishes. (Focused on young of year, juvenile, and adults to determine size frequency distribution, densities [via catch rates] and assessment of fish health.	Determine historic and current character and structure of species populations. Determine historic & current life-history & habitat requirements of species. (Habitat, spacing, food source, interdependence, etc.) Define impacts of alternative flow regimes on species population character and structure. Determine requirements to maintain/enhance self sustaining populations of species.	Spawning and rearing temperature, salinity, DO requires of humpback chub. Possible downward trend in LCR adult numbers over last 10 years derived from mark recapture data; similar downward trend in mainstem not noted. Have limited information on historic occurrence and distribution of native fishes and species composition of the community. Know temperature regimes necessary for successful spawning and reproduction of most fishes. Know diet, early life history requirements of most fishes from literature. Incomplete data from Grand Canyon Most native fish spawn in warm tributaries, some larvae drift to the mainstem. Some larvae rear in larger warm water tributaries (LCR, Kanab). Small juveniles found in backwaters and tributaries, larger juveniles move to main channel near shore habitats. Know species composition, size distributions, general life spans, sex ratios of fish communities.	Ecology information (diet, habitat requirements, predation, etc.) for humpback chub in Little Colorado River. PIT tag data repository for all of river system. Energetics of T&E sensitive species. Parasite, disease, life history and related interactions of native and nonnative fish. Ecological information (diet, cycles, requirements) for flannelmouth suckers, blue headed sucker, speckled dace. Validate data on fish assemblages. Structural and functional linkages of aquatic ecosystems, threatened and endangered and sensitive fishes. Effects of temperature variation and effects on fisheries in Lake Powell and river. Effects of rapid lake level drop on fisheries and endangered fish in Lake Powell.	Monitor fisheries of Lake Powell, if selective withdrawal is implemented. Monitor (numbers caught, catch per effort, length, weight, parasites, reproductive condition, PIT tag number) for all life stages of fish species in appropriate habitat types and locations. Establish and maintain a PIT tag data repository. Monitor flannelmouth sucker aggregations at tributary locations, including Paria, Kanab, Havasu, etc. Native species for monitoring include HBC, flannelmouth bluehead and razorback suckers, speckled dace. Match shoreline fish sites with shoreline vegetation	Test experimental enhancement of flannel mouth populations and other species through Paria River rearing ponds, including imprinting in Paria water. Determine the extent of food limitation on distribution and condition of native fish. Review potential diseases, parasites and other factors affecting fish length in the future. Evaluate food habits (gut contents) of flannelmouth sucker over time using non-lethal methods. Determine interrelationships between mainstem flow and backwater fish habitat (e.g. warming, geochemistry, food availability). Study of probable impacts of rapid drops in Lake Powell to biotic communities.

Monitoring and Research Planning
FISH AND AQUATIC RESOURCES
Other Native Fish #2

Stakeholder's Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
		Temperature effects data for larval flannelmouth	Character and structure of fish assemblage. Interactions of native fish and food base. Determine life history requirements (spawning, rearing habitat, diet) for native fish species. Effects of sampling efforts on fish populations.		

Monitoring and Research Planning
FISH AND AQUATIC RESOURCES
Trout

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
In Colorado River corridor below Glen Canyon Dam to the confluence with the Paria River, natural reproduced fish should compose at least 50% of the Age III rainbow trout. Sufficient suitable spawning habitat should be maintained to reach this objective. The total populations of rainbow trout (age II$^+$) in this reach should be maintained at approximately 100,000 fish as determined by population estimation. Rainbow trout should achieve 18 inches in length by Age III with a mean relative weight (Wr) of at least 0.80.	Determine ecosystem requirements, population character and structure to maintain reproduced populations of Age II$^+$ Fish at 50,000-100,000 population levels. Determine changes in population character & structure. Determine contribution of naturally reproduced fish to the population. Determine availability and quality of spawning substrates in Glen Canyon reach. Determine size of the population of Age II$^+$ rainbow trout in Glen Canyon reach. Determine growth and condition of rainbow trout in Glen Canyon. Define criteria for healthy trout population.	Approximately 75% of field sampled and creeled trout are naturally spawned under interim flows. During pre interim flows, approximately 25% of the fish were naturally spawned with the other 75% comprised of hatchery stocked fish. Know locations of some spawning bars (primarily shallow bars), location of redds (Yard maps). Know species composition, fish sizes and distribution (related to population character and structure). Know angler pressure, catch, harvest rates and percent of harvest comprised on naturally spawned fish. Know that few stocked trout move downstream from the Glen Canyon reach (related to population character and structure) under existing flow regimes. Know genetics of stocked trout (Bell-Aire strain). Know growth rates of stocked fish that have been marked with coded wire tags. Know condition and Wr of field sampled and creeled fish. Know Goode fish health index ratings for field sampled fish. Know that most trout carry parasitic trout nematode. Selenium levels in trout flesh appear to be higher than normal. General knowledge at relationship between river stage and laying of trout redds.	Food web energetics; re: how does algal mass relate to trout production. What is quantity and availability of spawning gravels in the reach? What is percentage of wild spawned fish under different flow regimes? What is genetic character of wild spawned fish? What are impacts of different regulations (slot limit, bag limits, gear restrictions) on character and structure of the trout population? What is growth of naturally spawned fish? What is status of disease and parasites in the fishery? What is impact of high Se levels on reproduction of trout? How does stage relate to stranding of redds and drying of spawning beds?	Monitor rainbow trout above Lees Ferry; reproduction, percent of population that is naturally spawned, downstream movement. Monitor harvested & field sampled rainbow trout to determine contribution of naturally reproduced fish to the population. Monitor changes in population character and structure. Monitor temperature regimes and effect on recreational use of fishery.	Determine the extent of food limitation on distribution and condition of fish. Review potential for growth-limiting factors affecting rainbow trout in the future, including diseases, parasites, etc. Develop an energetic model for trout incorporating lower trophic components. Determine carrying capacity for trout under different flow regimes. What stocking rates are appropriate to meet Stakeholders Objectives? Evaluate slot and bag limits using existing growth and survival information. Develop effective remote sensing techniques to evaluate changes in spawning gravel composition.

Monitoring and Research Planning
Fish and Aquatic Resources
NATIVE/NON-NATIVE FISH INTERACTIONS

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need to Know	Scientists' Monitoring Statements	Scientists' Research Questions
Minimize to the extent possible, interactions between native and non-native fishes.	Define areas & conditions of current & future existing & potential native and non-native fish interactions. Monitor key attributes associated with interaction. Determine methods for minimizing interactions with isolation Determine methods for minimizing interactions without isolation. Provide up-to-date information regarding species composition, relative abundance & size class structure of non-native fish in the Colorado River and important tributaries. Identify existing and potential sources of interaction (predatory, competitive) between extant non-native and native fish of the Colorado River and important tributaries. Evaluate effects of beach habitat building and habitat maintenance flows on the distribution & abundance of non-native fish in the Colorado River and important tributaries. Identify potential alternative strategies to suppress problematic non-native species in the Colorado River and important tributaries.	Brown trout, rainbow trout and channel catfish prey on humpback chub and flannelmouth sucker. Rainbow trout and humpback chub diets are similar. Channel catfish spawn primarily in the Little Colorado River. Brown trout spawn primarily in Bright Angel Creek area. Red shiners are abundant in Lake Mead inflow. Fathead minnow are present in tributaries. Carp are common throughout the system. Striped bass make annual spawning runs from Lake Mead. Walleye, largemouth bass, green sunfish, black bullhead are potential predators of native fish, but their numbers are currently low. Information on native and non-native fish interactions from work in the upper Colorado River basin.	Positive and negative linkages which define native and non-native fish interactions. Determine probable responses of all non-native species to selective withdrawal and steady summer flows. Verify extent of predation on native fish by brown trout, rainbow trout, and channel catfish. Usefulness of recreational fishing to control exotic fish. How does trout management in Glen Canyon affect native species? The effects non-native fish (carp, trout, catfish, minnows) have on larval and juvenile native fish in the Colorado River.	Monitor numbers and composition of all non-native fish populations. Important non-natives for monitoring include rainbow and brown trout, channel catfish, carp, fathead minnow, red shiner, Rio Grande killifish, striped bass. Monitor food habits of brown trout, rainbow trout, channel catfish, striped bass, walleye, carp. Monitor removal of channel catfish from Little Colorado River. Monitor removal of brown trout from Bright Angel Creek.	Test efficacy of experimental non-native fish control i.e.; the removal of non-native fishes and the response in the native fish population. How will populations of channel catfish and brown trout respond to removal? Determine potential for invasion of other aquatic species, especially under low steady flows or selected temperature withdrawals; zebra mussels, fish parasites, etc. Study native and non-native species interactions through controlled research (especially the impacts of various temperature regimes). Risk analysis of response by non-native fishes to selective withdrawal and steady summer flows. How do non-native fish affect the survival and recruitment of native fish.

Monitoring and Research Planning
FISH AND AQUATIC RESOURCES
Reasonable & Prudent Alternative

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Evaluate through monitoring and research the reasonable and prudent alternatives specified by the US Fish and Wildlife Service.	Using monitoring and research programs evaluate all test flows in RPA and potential impacts to threatened and endangered fisheries. Determine the benefits and impacts of installing selective withdrawal for thermal modification in the mainstem of the Colorado River downstream of Glen Canyon Dam.	Interim flows may have benefitted native fish. Interim flows may also benefit non-native fish. Red shiners, fathead minnows, and carp can thrive in warm river environments, e.g., upper basin. Temperature regime expected downstream of dam. Results of similar experiments at Shasta and Flaming Gorge Dams.	Risk analysis of selective withdrawal. Define impacts of alternative flow regimes on species population character and structure. Will the small increase in water temperature help native fish spawn in the mainstem and larvae to survive after entering the mainstem from the LCR. Determine the likelihood of shad, shiners, and stripped bass entering the system. Determine the affects on trout growth, primary productivity and invertebrates. Determine the likely changes in community structure and diversity among fish, invertebrates, and primary producers.	Establish baseline information regarding location and reproductive potential of non-native fish, in case selective withdrawal is implemented.	Risk analysis. Conduct study to relate probable changing temperature regimes to fisheries.

Needs Proposed in Biological Opinion

Attainment of riverine conditions that support all life stages of endangered and native fish species is essential to the Colorado River ecosystem.

The service believes that actions for one native species should be supportive of other native species in the ecosystem.

Reclamation and the Service will meet at least annually to coordinate reasonable and prudent alternative activities.

Determine humpback chub life history schedule for populations downstream of Glen Canyon.

Establish a second spawning aggregation of humpback chub downstream of Glen Canyon Dam.

Protect humpback chub spawning population and habitat in LCR by being instrumental in developing a management plan for this river.

Develop actions that will help ensure the continued existence of the razorback sucker.

Develop a management plan for the species in the Grand Canyon.

Monitoring and Research Planning

RIPARIAN AND TERRESTRIAL VEGETATION #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Preserve or restore (where possible) natural species composition & abundance within riparian and unplanned communities affected by dam operations.	1. Determine historical (pre-dam) natural composition of riparian and upland communities. 2. Characterize normal range of variation and ecology of species. 4. Evaluate impact of dam operations on establishment of and impacts from exotic plant species.	• Terrestrial vegetation divided into three zones: marsh, new high water, old high water. • Know extent of vegetated area and type of all vegetative communities. • GIS of some reaches; vegetation maps for reaches. • Cottonwoods are establishing. • Old high water zone vegetation is not reproducing. • Inundation levels and grain size control riparian vegetation in still water. • Conceptual successional model of marsh and sandbar vegetation. • Preferred alternative will reduce vegetation levels below current levels (elevation). • 13% of riparian plant species in canyon are exotic; accounts for 40% of area coverage. • Some exotics have become important to target species for conservation (e.g. Tamarisk/Southwest Willow Flycatcher) and watercress for KAS.	Information on changes to species composition, areal extent, and location of vegetation. Normal range of variation and ecology of species. • Quantitative successional vegetation models. • Nutrient dynamics in the inundation zone. • Groundwater/nutrients flows-how they relate to riparian vegetation.	Monitor species composition, abundance spread or contraction of vegetative communities below the dam. Monitor fate of old high water species (e.g. mesquite) in new riparian areas, under different flow regimes. Choice of locations for monitoring of riparian vegetation should partially be driven by other resource needs (wildlife, fisheries, sand bar erosion, campsites) and by existing datasets for 10 GIS geomorphic reaches. Monitor riparian habitat between Glen Canyon Dan and Lake Mead, as it is important to the Grand Canyon ecosystem. Monitor spread of non-native vegetation, camelthorn, Lepium latifolium, Eragnostis cerrula, Tamarisk, Russian olive. Monitor changes in extent and relative abundance of Willow and Tamarisk.	Determine effects of management alternatives on riparian vegetation: steady summer flows, habitat building flows. Explore GIS modeling the impacts of alternative flow regimes on riparian vegetation. Conduct basic life history studies of non-native vegetation: camelthorn, tree of heaven, Lepium lattifolium, Eragnostis cerrula.

Monitoring and Research Planning

RIPARIAN AND TERRESTRIAL VEGETATION #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Emphasize the preservation of unique plant communities and any special status species (federal, tribal, and state designations) to ensure their perpetuation within system.	1. Determine historic & current distributions, range of variation and ecology of T&E and special status species. 2. Establish ecosystem requirements of special status species and determine probable impacts of proposed flow regimes. 3. Determine population changes in special status species. 4. Determine impacts of operating criteria necessary to meet ecosystem requirements of special state species on other resources and ecosystems.	• There are no sensitive or endangered plant species listed along the river that are at risk.	• Linkage of terrestrial vegetation and aquatic food base for important T&E and specialists species. • Invertebrate productivity and relationships to vegetation and vegetation change.	Match shoreline fish sites with shoreline vegetation. Monitor location, size, number, and species composition of marsh habitats within riparian area. Monitor habitat for Willow flycatcher. Monitor distribution and abundance of vegetation needed by Kanab ambersnail	Determine, perhaps by GIS modeling, the extent of flooding riparian vegetation by river stage. Flooded riparian veg may be important fish habitat.

Monitoring and Research Planning

NATIVE TERRESTRIAL WILDLIFE RESOURCES #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Protect, restore and enhance survival of native and special status species. (Federal, Tribal, and State designations). Ensure that the required habitat for these species is preserved. Maintain native faunal components of the ecosystems for the benefit of T&E species.	Define and specify ecology of native faunal components, especially T&E species; including evolutionary and environmental changes, natural range of variation, linkages, interdependencies and requirements. Evaluate species population to detect departures from natural range of variation. Determine changes, declines in special status species & characterize ecosystem changes to benefit species.	Distribution and relative abundance of amphibians along the river corridor (surveys in 1970's). Distribution, abundance, age class distribution, habitat use, and genetic characteristics of isolated Leopard Frog population at RM-9 along the river corridor (surveys and research in 1994-1996). Distribution and relative abundance of reptiles along the river corridor (surveys in 1970's). Distribution, relative abundance, habitat affinities, and ecology of general bird community along the river corridor (surveys in 1970s-1900s). Food habits of selected insectivorous birds along the river corridor. Terrestrial-origin insects predominate in diet of these birds. Distribution, abundance, habitat affinities, and breeding ecology of the Southwestern Willow Flycatcher along the river corridor (surveys in 1980s-1990s). Also know the strong negative impacts of Brown-headed Cowbird nest parasitism on flycatcher productivity. Distribution, abundance, habitat use, human disturbance patterns, and feeding ecology of wintering feeding ecology of wintering Bald Eagles along the river corridor (surveys in late 1980s-1990s).	Evaluate changes in vertebrate species densities as a result of increase in riparian vegetation (e.g. Neotropical migrants). Are amphibians responding (population sizes and/or distribution) to past and future changes in aquatic. Is this isolated frog population viable in the long-term? How will future changes in aquatic and riparian systems particularly possible warming of fiver) effect this genetically distinct population? Are reptiles responding (population sizes and/or distribution) to past and future changes in riparian habitat? How ill bird community respond (population sizes and/or distribution) to future changes in aquatic and riparian habitats? Is this isolated population of Willow Flycatchers viable in the long-term? How will future changes in riparian habitats effect flycatcher distribution, abundance, and breeding ecology/ what is the source of the cowbirds that are parasitizing the flycatchers? Will changes n the aquatic system influence Bald Eagle use of the river corridor for winter foraging, particularly at trout spawning sites such as Nankoweap Creek.	Vegetation and bird monitoring should be closely linked. Monitor endangered birds, number, and habitat. Monitor Willow flycatcher in relation to vegetation community structure. Monitor distribution and abundance of riparian corridor amphibians. Monitor distribution, abundance, reproductive status/ success, and age-class distribution of Leopard Frogs at FM-9 site. Monitor distribution and abundance of riparian corridor reptiles. Monitor distribution and abundance of riparian corridor bird community. Monitor distribution abundance, and breeding success of riparian corridor bird community. Monitor distribution, abundance, and breeding success of breeding success of Peregrine Falcon. Monitor distribution and abundance of riparian corridor mammals. Monitor distribution and abundance of bats and bat roost sites along the riparian corridor	Willow flycatcher. How many territories? Where are they producing young? More attention should be placed on upper Lake Mead and tributaries of Lake Mead and tributaries of Lake Powell. Is Brown-headed Cowbird parasitism negatively affecting the abundance and/or distribution of other bird species? If so, what management alternatives can counteract this effect? What techniques are most effective for long-term monitoring of bird community? Is he flycatcher population along the river corridor genetically and reproductively isolated? To what other regional Willow flycatcher populations are these birds most closely related (genetically). What are the "sources" of cowbirds found parasitizing flycatcher nests along the river? What management actions can be taken to reduce or eliminate parasitism? How will increased water temperatures influence food base (fish) and foraging conditions?

Monitoring and Research Planning
NATIVE TERRESTRIAL WILDLIFE RESOURCES #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
		Distribution, abundance (a very large population), habitat use, and feeding ecology of Peregrine Falcons along the river corridor (surveys in late 1980s-1990s). Distribution, abundance, and habitat use of wintering waterfowl along the river corridor above Lees Ferry (regular surveys in mid 1990s). Distribution, abundance, and habitat use of wintering waterfowl along the river corridor below Lees Ferry (opportunistic surveys in 1980s-1990s). Distribution and relative abundance of mammals along the river corridor (surveys in 1970s). Distribution and relative abundance of bats along the river corridor, with limited data on breeding and roost sites. Distribution and habitat affinities of terrestrial insects along the river corridor with limited data on ecology and relative abundance. Distribution, abundance, habitat affinities and general ecology of the Kanab Ambersnail at Vasey's Paradise (surveys and research in 1990s).	Will changes in the aquatic and riparian systems (as manifested in food base) influence Peregrine Falcon use of the river corridor particularly with regard to breeding? Needs met. The current understanding of waterfowl ecology suggests that external factors strongly dominate and influence local waterfowl abundance. Needs met. The current understanding of waterfowl ecology suggests that external factors strongly dominate and influence local waterfowl abundance. Are mammals responding (population sizes and/or distribution) to past and future changes in aquatic and riparian habitats? Identification of additional roost sites, with emphasis on maternal colonies. Increased understanding of ecology of bats, including movements, habitat use, and foraging needs and patterns. How are bats influenced by river operations (e.g., diet), visitation (e.g., disturbance at roost), etc. Species present, and their ecologies, particularly in regard to riparian vegetation. Is this isolated population of Kanab Ambersnails viable in the Long-term? How are snails affected by predation, parasitism, and disease?	Standardized invertebrate monitoring difficult and impractical. May eventually target keystone species. Monitor distribution and abundance of Kanab Ambersnails. Survey for new populations along the river corridor.	

Maintain a natural age-class distribution throughout the majority of their natural range in Glen and Grand Canyons, emphasizing the need to recruit into breeding age classes.	Determine species natural ranges (pre-post dam). Determine historic age class distribution (pre-post dam). Assess natural range & age class distribution,, changes, constraints, probable long term viability implications to species; assess alternate habitat, ecology associations (specifically age class); and ecosystem associations. Monitor impacts of alternative operating criteria on ecosystem & ecology requirements of species.		Ecology in these settings not fully known.	Specific items noted under previous objectives identify monitoring needs for most species and groups.	Assessment of current knowledge on distribution abundance, and life history of riparian reptiles and mammals. Determine significance of post dam vegetated corridors to range extensions and interbreeding among previously isolated populations of amphibians and reptiles.
Evaluate the viability of food chains for native fauna, including the Peregrine Falcon, S.W. Willow Flycatcher, and other special status species.	Define food chain associations, interdependencies, requirements, etc.; for native species population targets. Monitor impacts of alternative operating criteria on food chain associations.	Basic understanding of the feeding habitats and food base of most terrestrial vertebrates in the Canyon. Food does not appear to be a limiting factor to any known species, although local abundance of wintering eagles may be influenced by availability of spawning trout.	How does the food base / food chain affect the ecologies of bats, Kanab Ambersnails and other species of concern along the river corridor?	Monitor abundance of food organisms important to special status species.	Determine food habits of bats and Ambersnails. Determine potential and suitable alternative food sources for Ambersnails.
In as much as management is not deleterious to naturally occurring ecosystem components, consider & mitigate impacts to special status species that may use the river corridor opportunistically. Maintain self sustaining fish populations as forage to provide opportunities for bald eagles. Monitor for nesting.	Characterize historic and current use or expected use of area by species. Determine habitat, forage, nesting, etc.; requirements based on current or future use.	Bald Eagle. May use river corridor in winter, but not historically occurring. Concentrated near Nankoweap drainage. This appears to be directed mainly at the Bald Eagle. Distribution, abundance, habitat use, human disturbance patterns, and feeding ecology of wintering Bald Eagles along the river corridor (surveys in late 1980s-1990s) already well known and understood.	Will changes in the aquatic system influence Bald Eagle use of the river corridor for winter foraging, particularly at trout spawning sites such as Nankoweap Creek.	General avian community monitoring. Determine what species are breeding, relative abundance, etc. Monitor bat populations and habitats. Not applicable for Bald Eagle (unless selective withdrawal or other major changes to aquatic system are implemented).	How will increased water temperatures influence the Bald Eagle food base (fish) and foraging conditions? To what degree are Bald Eagles dependent on the trout resources at Nankoweap during the winter/

Monitoring and Research Planning
NATIVE TERRESTRIAL WILDLIFE RESOURCES #4

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
The population of Kanab Ambersnail should be inventoried and maintained near current levels. Efforts to establish additional population center should be guided by the recovery plan for the species.	Characterize historical and current populations of Kanab Ambersnail and their locations. Determine ecology & ecosystem related requirements for Kanab Ambersnail to enhance 1996 levels. Monitor changes in populations, health, and character of Ambersnail. Identify areas of possible future use.	Kanab Ambersnail populations.	Need second population of Kanab Ambersnail established.	Monitor Kanab Ambersnail for compliance. Monitor Kanab Ambersnail populations above 60,000 cfs. Monitor occurrence of Kanab Ambersnail trematode parasite. Monitor abundance and food habits of Peromyscus predator at Vaseys Paradise.	Determine definitive host of Kanab Ambersnail trematode parasite. Identify other areas of habitat potentially suited to KAS (within and outside of NPS areas).
Maintain a diversity of wildlife species associated with ongoing natural evolutionary and ecological processes, giving priority to native species.	Determine the historical and current wildlife occupying or using habitats in the Canyon. Determine range of natural variability, ecology and ecosystem requirements of species. Monitor impacts of operating criteria on wildlife with emphasis on special status species.	GIS map of upper Lake Mead, physical areas not delineated. Upper Lake Powell regarding riparian vegetation, neotropical migrant birds, native and nonnative fish. Know location and vegetation requirements of some mammals. Amphibian distribution is roughly known, not densities.	Reptile ecologies, densities, and diversity. Use of shoreline marshes by vertebrate (waterfowl, other birds, bighorn, deer, etc.). Need an assessment of current knowledge on distribution, abundance, and life history of riparian herptiles and mammals. Little is known, hard to determine effects of dam operations without an information base.	Distribution and abundance of large mammals should be determined at 5-year intervals. Distribution and abundance of reptiles and amphibians. Should be determined at 5-year intervals. Monitor abundance of RM-9 leopard frogs. Monitor bat populations and habitats.	Determine food habitat of terrestrial vertebrates and effects of and on changing vegetative communities: bighorn sheep and rushes, beaver and cottonwood. Invertebrate inventory of GCNRA and GCNP.

NRC Concerns
1. Link biotic studies with each other, and integrate with hydrological and geomorphic studies that would make the essential connection to operations.

Monitoring and Research Planning

RECREATION #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Provide quality recreation experiences that do not adversely affect natural or cultural resources. Maintain or improve wilderness character of the recreational experience.	Determine criteria and aspects that are important to or detract from wilderness experience. Characterize procedures to mitigate those aspects of flows that detract from wilderness character of river. Determine the impact of scientific studies on wilderness character and experience.	Accident data on boating/fishing. Discharge levels and related satisfaction of boaters.	Recreational expectations of Glen and Grand Canyon visitors.		Determine visitor knowledge, expectation, perceptions and experience related to wilderness river recreation.
Maintain flows and sediment processes that create adequate beach character and structure for camping.	Determine adequate beach quality character and structure for camping throughout system. Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resource, quality, character and structure. Monitor beach character and structure changes. Develop systems models to predict flow regimes for building & maintaining beaches.	Beach areas as related to interim flows, floods below Paria.	Beach area from interim flows and floods in Glen Canyon reach.	Compile and use aerial photography, videos, etc.; to evaluate flow regimes on camp size, quality and number. Establish cooperative monitoring with boatman and fishermen on fisheries resource change.	Determine relationship of impacts through time of debris flows on sites of recreation campsites through models.
Maintain flows that do not preclude navigability by whitewater craft in the Grand Canyon and power craft in Glen Canyon and upper Lake Meade.	Determine if operating criteria maintain adequate power craft navigability in Glen Canyon and upper Lake Mead and safe access by recreational users. Determine if operating criteria maintain white water raft navigation in Grand Canyon. Define ecosystem & other resource impacts of flow regimes to maintain navigation. Evaluate the effects of operations as prescribed in the preferred alternatives on recreational safety.	Glen Canyon discharge and related "accident" data such as boats and motors striking bottom. Adequate flows for white water rapids.	Improved "accident" data (rates, locations). Evolution of rapids in waterway and effects on navigation. Visitor/boat carrying capacity of river corridor by reach.		Study of probable impacts of rapid drops in Lake Powell and the effects on recreational uses. Using flight data, assess impacts of flow regimes on boating capacity in reaches with critical resources. Using recreation study assessments completed, determine probable impacts to recreation expectations under different flow regimes.

Monitoring and Research Planning

RECREATION #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Maintain cold water fisheries opportunity (100,000 age adult II^{+}) in Glen Canyon.	Determine flow regimes necessary to maintain continuous access to quality of the angling opportunity. Determine impacts of operating criteria on other resources and ecosystems.	Angler satisfaction and use at various flow levels.	Monitoring of angler use and satisfaction.	Establish cooperative monitoring with boatman and fisherman on fisheries resource change.	
Maintain sport hunting opportunities for waterfowl in Glen Canyon.	Define pattern of waterfowl use and conflicts to other uses. Define pre- and post-dam waterfowl use. Determine effects of flow regimes on waterfowl usage.	Waterfowl are highly mobile and population size is strongly affected by factors outside the parks.	Effects of dam operation on bird populations and sports hunting.		Assess potential effects of dam operations on important waterfowl species.

Monitoring and Research Planning

HYDROPOWER

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Maximize the value of long-term firm power and energy generation within the criteria and operating plans established by the Secretary under Section 1804 of the Grand Canyon Protection Act.					

APPENDIX B
INFORMATION (PLANNING) GROUP PARTICIPANTS

Name	Affiliation
Mark Anderson	US Geological Survey
Jan Balsom	National Park Service
Gregg Bowen	Navajo Nation
Clay Bravo	Hualapai Nation
Gary Burton	Western Area Power Authority
Kerry Christensen	Hualapai Nation
Dave Cohen	Trout Unlimited
Wayne Cook	Upper Colorado River Commission
Bill Davis	EcoPlan Assoc./CREDA
Kurt Dongoske	Hopi Tribe
Alan Downer	Navajo Nation
Robert Forrest	EcoPlan Associates
L. D. Garrett	Grand Canyon Monitoring and Research Center
Barry Gold	Grand Canyon Monitoring and Research Center
Owen Gorman	US Fish & Wildlife Service
Julie Graf	US Geological Survey
Terry Gunn	Lees Ferry Anglers
Robert Hart	US Geological Survey
Norm Henderson	NPS Glen Canyon
Tom Hine	Arizona Power Authority
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Loretta Jackson	Hualapai Nation

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APPENDIX B
INFORMATION (PLANNING) GROUP PARTICIPANTS

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Cynthia Osife	Southern Paiute Consortium
Clayton Palmer	Western Area Power Authority
Bill Persons	Arizona Game and Fish Dept.
Randall Peterson	Bureau of Reclamation
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Mark Phillips	Trout Unlimited
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Larry Riley	Arizona Game and Fish Dept.
Frank Ronco	Northern Arizona Flycasters
George Ruffner	EcoPlan Assoc./CREDA
Maggie Sacher	Lees Ferry Lodge
Larry Stevens	Grand Canyon Monitoring and Research Center
David Trueman	US Bureau of Reclamation
Bill Vernieu	Grand Canyon Monitoring and Research Center
Robert Winfree	National Park Service

Michael Yeatts	Hopi Tribe

APPENDIX C - BIOLOGICAL RESOURCES PROGRAM STAKEHOLDER OBJECTIVES AND INFORMATION NEEDS

I. FISH AND AQUATIC RESOURCES

Aquatic Food Base

S.O. 1: Maintain and enhance the aquatic food base in Glen and Grand Canyons. Maintain continuously inundated areas for Cladophora and aquatic invertebrates at or above 5,000 cfs discharge.

S.I.N. 1.1: Define current and historic food base character and structure
S.I.N. 1.2: Define food base character, structure and requirements for maintaining target populations of Humpback Chub, other native fish, and rainbow trout
S.I.N. 1.3: Determine system changes attributes; manipulations to maintain/enhance food base
S.I.N. 1.4: Define impacts of alternative operating criteria on ecosystem (food base)
S.I.N. 1.5: Monitor the species composition and the distribution of aquatic algae and macrophytes in the Colorado River
S.I.N. 1.6: Monitor the species composition and density of macroinvertebrates in the Colorado River

Humpback Chub

S.O. 2: Maintain or enhance the existing population of humpback chub at or above 1987 levels determined by April/May hoop-net monitoring in the lower 1,200 meters of the Little Colorado River. (Focused on fish >200mm, and should include a fish health assessment.) Maintain levels of recruitment of humpback chub in the mainstem and Little Colorado River, as indexed by size frequency distributions and presence and strength of year-classes. (Focused at young-of-year and juvenile fish, and should include a fish health assessment.)

S.I.N. 2.1: Monitor adult humpback chub populations and evaluate population level trends
S.I.N. 2.2: Monitor levels of recruitment of humpback chub in the mainstem and the LCR
S.I.N. 2.3: Monitor quantity and quality of chub backwater and near shore habitat in mainstem
S.I.N. 2.4: Determine and identify surrogate health factors for evaluation of native or non-native fishes.
SI.N. 2.5: Develop a backwater quality index, using existing data for humpback chub
S.I.N. 2.6: Evaluate impacts of sampling methods and recreation use on native fish populations

S.O. 3: Establish a second, self sustaining population of humpback chub by 2005, contingent on feasibility. Monitor for spawning and determine the contribution of other existing aggregations as one component of assessing feasibility.

S.I.N. 3.1: Develop criteria for self sustaining populations of humpback chub
S.I.N. 3.2: Assess feasibility of second population including other current aggregations

I. FISH AND AQUATIC RESOURCES (continued)

Other Native Fish

S.O. 4: Verify the status of and management for healthy, self sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the mainstem Colorado River in Grand Canyon and its tributaries. Verify the status of and management for healthy, self sustaining populations of native fish in Glen Canyon based upon the capability of the habitat to support those fishes. (Focused at young-of-year, juvenile, and adults to determine size frequency distributions, densities [via catch rates], and assessment of fish health.)

S.I.N. 4.1: Determine current character and structure of species populations
S.I.N. 4.2: Determine ecosystem requirements (habitat, spacing, food source, interdependencies, etc.) of species relative to historic and current conditions in Glen Canyon
S.I.N. 4.3: Monitor and define impacts of alternative flow regimes on species population character and structure
S.I.N. 4.4: Determine requirements to maintain/enhance self-sustaining populations of species

Trout

S.O. 5: In the Colorado River corridor below Glen Canyon Dam to the confluence with the Paria River, natural reproduced fish should compose at least 50% of the Age III rainbow trout. Sufficient suitable spawning habitat should be maintained to reach this objective. The total populations of rainbow trout (age II plus) in this reach should be maintained at approximately 100,000 fish as determined from population estimation. Rainbow trout should achieve 18 inches in length by Age III with a mean relative weight (Wr) of at least 0.80.

S.I.N. 5.1: Determine ecosystem requirements , population character and structure to maintain reproducing populations of Age II plus fish at 50,000 - 100,000 population levels
S.I.N. 5.2: Monitor changes in population character and structure
S.I.N. 5.3: Monitor harvested and field sampled rainbow trout to determine the contribution of naturally reproduced fish to the population
S.I.N. 5.4: Monitor the availability and quality of spawning substrates in the Glen Canyon reach
S.I.N. 5.5: Monitor the size of the population of age II plus rainbow trout in the Glen Canyon reach
S.I.N. 5.6: Monitor the growth and condition of rainbow trout in Glen Canyon
S.I.N. 5.7: Define criteria for healthy trout population

I. FISH AND AQUATIC RESOURCES (continued)

Native / Non-Native Fish Interactions

S.O. 6: Minimize, to the extent possible, interactions between native and non-native fishes.

S.I.N. 6.1: Define areas and conditions of current, future and potential interactions
S.I.N. 6.2: Monitor key attributes associated with interaction
S.I.N. 6.3: Determine methods for minimizing interactions through isolation
S.I.N. 6.4: Determine methods for minimizing interactions without isolation
S.I.N. 6.5: Monitor the species composition, relative abundance, and population structure of non-native fishes in the Colorado River and important tributaries
S.I.N. 6.6: Identify existing and potential sources of interaction (predatory, competitive) between extant non-native fishes and native fishes of the Colorado River and important tributaries
S.I.N. 6.7: Evaluate the effects of beach/habitat building flows and habitat maintenance flows on the distribution and abundance of non-native fishes in the Colorado River and important tributaries
S.I.N. 6.8: Identify potential alternative strategies to suppress problematic non-native species in the Colorado River and important tributaries

Reasonable and Prudent Alternative

S.O. 7: Evaluate through monitoring and research the reasonable and prudent alternatives specified by the US Fish and Wildlife Service.

S.I.N. 7.1: Using monitoring and research programs evaluate all test flows in RPA and potential impacts to threatened and endangered fisheries
S.I.N. 7.2: Determine the benefits and impacts of installing selective withdrawal for thermal modification in the mainstem of the Colorado River downstream of Glen Canyon Dam

II. RIPARIAN AND TERRESTRIAL VEGETATION

S.O. 1: Preserve or restore (where possible) natural species composition and abundance within riparian and upland communities affected by dam operations.

S.I.N. 1.1: Determine historical natural composition of riparian and upland communities
S.I.N. 1.2: Characterize normal range of variation and ecology of species
S.I.N. 1.3: Monitor impacts of operating criteria on the succession processes of natural vegetation communities
S.I.N. 1.4: Evaluate impacts of dam operations on establishment of and impacts from exotic plant species
S.I.N. 1.5: Evaluate impacts to vegetation communities of alternate aspects of operating criteria

S.O. 2: Emphasize the preservation of unique plant communities and any special status species (Federal, Tribal, and State designations) to ensure their perpetuation within the system.

S.I.N. 2.1: Determine historic and current distributions, range of variation and ecology of T&E and special status species
S.I.N. 2.2: Establish ecosystem requirements of special status species and determine probable impacts of proposed flow regimes
S.I.N. 2.3: Monitor population changes in special status species

III. NATIVE TERRESTRIAL WILDLIFE RESOURCES AND HABITAT

S.O. 1: Protect, restore, and enhance survival of native and special status species (Federal, Tribal, and State designations). Ensure that the required habitat for these species is preserved. Maintain native faunal components of the ecosystems for the benefit of threatened and endangered species.

S.I.N. 1: Define and specify ecology of native faunal components, especially threatened and endangered species; including evolutionary and environmental changes, natural range of variation, linkages, interdependencies, and requirements
S.I.N. 2: Monitor species population to detect departures from natural range of variation
S.I.N. 3: Monitoring changes, declines in special status species and characterize ecosystem changes to benefit species

S.O. 2: Maintain a natural age-class distribution through out the majority of their natural range in Glen and Grand Canyons, emphasizing the need to recruit into breeding age classes.

S.I.N. 2.1: Determine species' natural ranges (pre and post dam)
S.I.N. 2.2: Determine historic age class distribution (pre and post dam)
S.I.N. 2.3: Assess natural range and age class disruption, changes, constraints, probable long-term viability implications to species; assess alternate habitat, ecology associations (specifically age class); and ecosystem associations
S.I.N. 2.4: Monitor impacts of alternative operating criteria on ecosystem and ecology requirements of species.

S.O. 3: Evaluate the viability of food chain(s) for native fauna, including the Peregrine Falcon, Southwestern Willow Flycatcher, and other special status species.

S.I.N. 3.1: Define food chain associations, interdependencies, requirements, etc., for native species population targets
S.I.N. 3.2: Monitor impacts of alternative operating criteria on food chain associations

S.O. 4: In as much as such management is not deleterious to naturally occurring ecosystem components, consider and mitigate impacts to special status species that may use the river corridor <u>opportunistically</u> (Bald Eagle). Maintain self-sustaining fish populations as forage to provide opportunities for bald eagles. Monitor for nesting.

S.I.N. 4.1: Characterize historic and current use or expected use of area by species
S.I.N. 4.2: Determine habitat, forage, nesting, etc.; requirements based on current or future use

III. NATIVE TERRESTRIAL WILDLIFE RESOURCES AND HABITAT (continued)

S.O. 5: The population of Kanab Ambersnail should be inventoried and maintained near current levels. Efforts to establish additional population center should be guided by the recovery plan for the species.

S.I.N. 5.1: Characterize historical and current populations of Kanab Ambersnail and their locations
S.I.N. 5.2: Determine ecology and ecosystem related requirements for Kanab Ambersnail to enhance 1996 levels
S.I.N. 5.3: Monitor changes in populations, health, and character of Ambersnail

S.O. 6: Maintain a diversity of wildlife species associated with ongoing natural evolutionary and ecological processes, giving priority to native species.

S.I.N. 6.1: Determine primary and secondary predatory areas, standing crop of attached vegetation communities and associated invertebrate communities and monitor on a seasonal basis
S.I.N. 6.2: Determine the historical and current wildlife (special status and migratory species, including waterfowl) occupying or using habitats in the Colorado riverine corridor
S.I.N. 6.3: Determine range of natural variability, ecology and ecosystem requirements of species
S.I.N. 6.4: Monitor impacts of operating criteria on wildlife with emphasis on special status species