EXECUTIVE SUMMARY

THE GCMRC FY 2001 ANNUAL WORK PLAN

INTRODUCTION

The Fiscal Year 2001 (FY 2001) Grand Canyon Monitoring and Research Center (GCMRC) Annual Monitoring and Research Work Plan (Work Plan) describes the scientific activities planned by GCMRC for FY 2001.[1] The FY 2001 Work Plan is designed to implement the adaptive management and ecosystem science approaches called for in the 1992 Grand Canyon Protection Act (GCPA), the Glen Canyon Dam Environmental Impact Statement (GCDEIS, 1995) and the Record of Decision (ROD, 1996).

GEOGRAPHIC AND INSTITUTIONAL SCOPE

The geographic scope of GCMRC's activities is the Colorado River ecosystem within Glen Canyon National Recreation Area and Grand Canyon National Park (Figure 1.1). The Colorado River ecosystem[2] is defined as the Colorado River mainstem corridor and interacting resources in associated riparian and terrace zones, located primarily from the forebay of Glen Canyon Dam (GCD) to the western boundary of Grand Canyon National Park, a distance of approximately 293 river miles. The scope of GCMRC activities includes limited investigations into some tributaries (e.g., the Little Colorado and Paria Rivers). It also includes, in general, cultural resource impacts of dam operations for inundation levels associated primarily with flows

1 Current Management Objectives and Information Needs have been used by GCMRC as the basis for developing the FY 2001 Annual Plan.

2 "Colorado River ecosystem" will be used throughout this document as the standard definition of the monitoring and study area for GCMRC. This definition is consistent with that used in the FY 1997-2002 Strategic Plan.

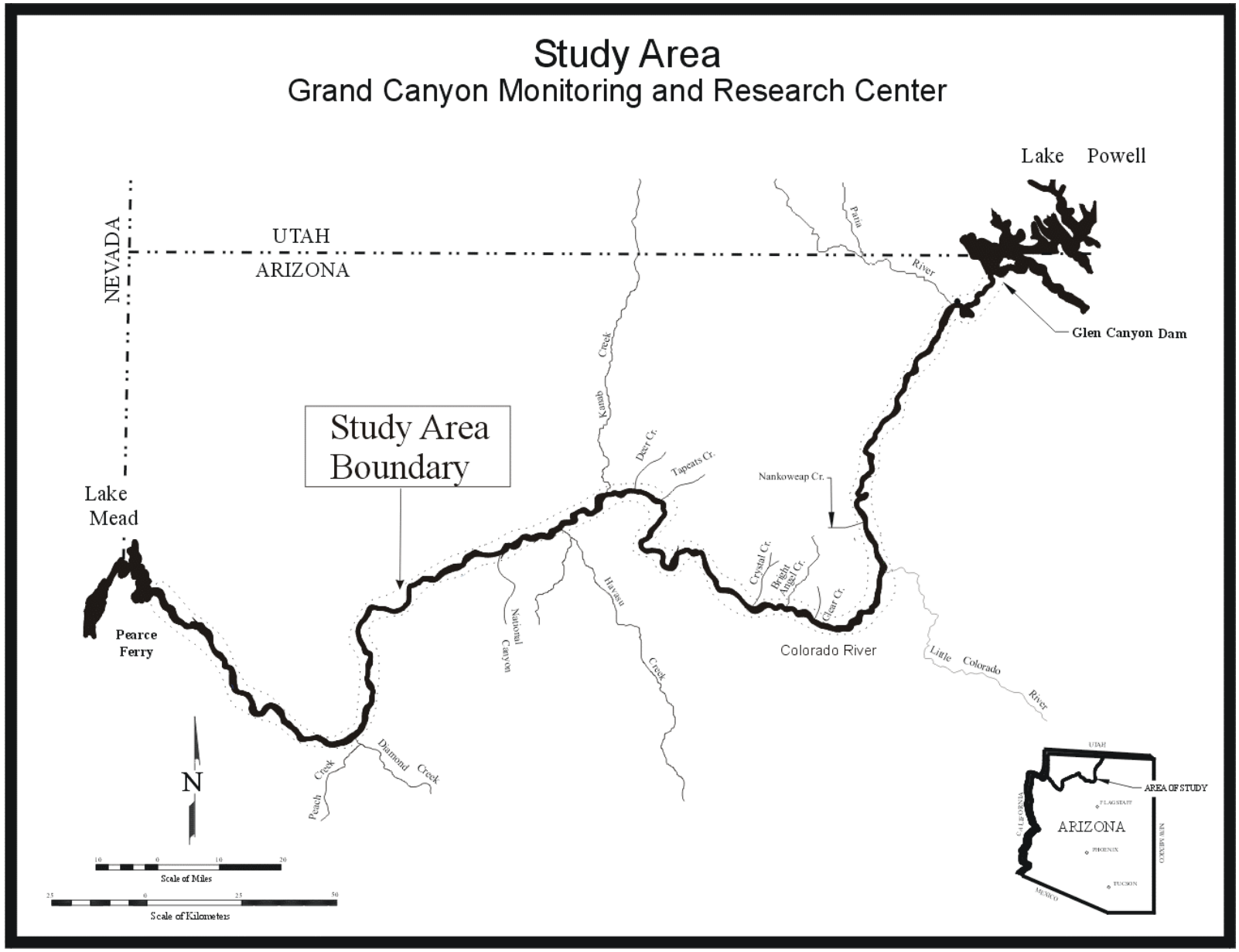

Figure 1.1 Map of Grand Canyon Monitoring and Research Center Study Area.

up to 256,000 cubic feet per second (cfs) as addressed in the Programmatic Agreement[3], and for physical, biological, recreational and other resources, impacts of dam operations for inundation levels associated primarily with flows up to 100,000 cfs. In between these levels, stakeholder concerns with respect to relict native vegetation, endangered species, and cultural resources may require activities by the GCMRC. All proposed projects relate to scientific activities intended to obtain information on "... the effects of the Secretary's actions[4]..." primarily on downstream resources located in the Colorado River ecosystem.

GCMRC scientific activities are constrained to those probable effects on downstream resources associated with dam operations; for this reason upstream monitoring by GCMRC in Lake Powell, and downstream in tributaries, (i.e., Little Colorado River) are constrained by design. Participants in the Glen Canyon Dam Adaptive Management Program (GCDAMP) realize these to be constraints that inhibit understanding of the entire ecosystem and therefore accept that scientific information from programs outside the GCDAMP may be needed as a means of strengthening understanding of the entire Colorado River ecosystem. Nevertheless, the ultimate purpose of GCMRC monitoring and research activities is to develop information on changes in the Colorado River ecosystem related to "... the effects of the Secretary's actions..." primarily on "downstream resources."

MISSION OF GCMRC[5]

The GCPA 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. The mission of the GCMRC is:

> "To provide credible, objective scientific information to the GCDAMP on the effects of operating Glen Canyon Dam on the downstream resources of the Colorado River ecosystem, as well as other information needs specified by the AMWG, utilizing an ecosystem science approach. "

3 The Programmatic Agreement, finalized in August 1994, is a legal agreement between federal and state agencies and tribal groups that specifies the responsibilities of the parties to comply with the National Historic Preservation Act (1996; 1992) and 36 CFR 800.
4 As specified in the 1992 GCPA and in the Record of Decision for the Glen Canyon Dam EIS (DOI 1996).
5 See Appendix 1 for the GCMRC Mission statement and Roles and Responsibilities.

ENSURING OBJECTIVE, QUALITY SCIENCE

The GCMRC was established to provide objective, high quality scientific information to the Secretary of the Interior and to the Adaptive Management Work Group (AMWG). To accomplish these goals, specific protocols regarding science planning, competition, peer review, administration and publication have been established[6]. The quality and objectivity of GCMRC research findings is ensured through competition and independent external scientific peer review. All proposals, data, reports, etc., are reviewed by independent, external scientists as well as by the GCMRC science team.

GCMRC SCIENTIFIC ACTIVITIES

The FY 2001 Work Plan describes monitoring and research activities that address the management objectives (MOs) and prioritized information needs (INs)[7] of the GCDAMP. Long-term monitoring is designed to determine changes in resource attributes. Research is used to improve monitoring, 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 operates an information technologies program to ensure information management (e.g., DBMS, GIS, Library), data analysis (e.g., GIS), and data dissemination to managers and stakeholders and science organizations (e.g., WWW), a surveying department to provide consistent, quality, cost-effective support to monitoring and research projects, and a logistics program to provide cost-effective support to monitoring and research field activities.

CURRENT KNOWLEDGE

Sediment and Water Resources – Since 1998, monitoring and research of sediment and water resources of the Colorado River ecosystem has continued under the GCRMC program as part of

6 Operating Protocols for GCMRC, June, 1996 and GCMRC Peer Review Guidelines, May 31, 1997.
7 The MOs and prioritized IN's adopted at the July 1998 AMWG meeting serve as the basis for the monitoring and research activities called for in the FY 2001 Work Plan. These can be found in Appendix 1.

a "transition" from EIS activities initiated under the Glen Canyon Environmental Studies (GCES), toward implementation of long-term monitoring. Following are summaries of preliminary results of the current physical research and monitoring projects funded under FY 1998 through 2000 agreements with the U.S. Geological Survey - Water Resources Division, Utah State University (USU), Northern Arizona University (NAU) and Ecometric Research, Inc.

Main Channel and Gaged Tributary Streamflow and Sediment (USGS): Under the current agreement with the USGS-Arizona District, unit-values for streamflow continue to be acquired at four main-channel (river miles 0, 61, 87 and 225) and two tributary gaging locations (Paria River at Lees Ferry and Little Colorado River near Cameron) operated by the Water Resources Division. Daily mean discharges, 15-minute unit values, and data on several quality of water parameters for streamflow are currently available for these GCMRC-supported sites through either GCMRC or USGS web pages. Suspended-sediment and bed grain-size samples continue to be collected and analyzed on an intermittent basis to better document the fine-sediment budget below Glen Canyon Dam, and to support research aimed at documenting relationships between suspended-sediment transport rates and evolving bed grain-size distributions following tributary inputs of fine sediment (Rubin, Topping, Anima, and Hornewer). A theoretical, process-based conceptual model for sediment routing along the main channel has also been developed under the current project (Wiele and others), and provides the basic strategy for development of a 1-dimensional fine-sediment routing model for tracking tributary inputs below Glen Canyon Dam.

Ungaged Tributary Sediment Inputs (USGS): Dr. Robert Webb of the USGS, has estimated ungaged tributary contributions for both fine and coarse sediments between Glen Canyon Dam and Upper Lake Mead. Preliminary results of this research are currently being externally reviewed, but indicate that as an average-annual minimum, inputs of sand from ungaged tributaries in Glen and Marble Canyons are approximately twenty percent of the Paria River's annual sand contribution. This is important information that further supports development of a fine-sediment budget for the ecosystem.

Sediment Input Models for Paria and Little Colorado Rivers (USGS): Between 1991 and present, Dr. David Topping of the USGS Water Resources Division's National Research Program, has developed geomorphically based flow and sediment-transport models for the major

tributaries that contribute fine-sediment to the ecosystem. The Paria River model has been undergoing a verification process for flood inputs that occurred in Water Years 1997 through 1999, and to date has performed well in estimating sand and finer inputs to the main channel. A similar model for the Little Colorado River is still in the final phase of development, but is expected to be completed by the end of FY 2000. Long-term monitoring protocols have been established by Topping for tracking physical channel changes within each river's modeling reaches related to model assumptions and performance. The characteristics of the channel to be tracked through long-term monitoring are those related to key model parameters such as channel geometry and bed grain-size stability. Verification of both of these flow and sediment models will continue under USGS-Arizona District activities as future tributary floods occur. The main objective for developing these models is to provide accurate volumetric and grain-size estimates of fine-sediment loads (sand and silt/clay) that influence the main-channel sediment budget following tributary floods.

Synthesis of Historical Geomorphic and Hydrologic Data (USU and USGS): This synthesis research project for geomorphology, sediment-transport and streamflow is being conducted jointly by USGS (Topping) and Utah State University (Schmidt). The initial phase of the synthesis (Lees Ferry to Phantom Ranch) is scheduled for completion by the end of calendar year 1999. The second phase of the research is focused on the Glen Canyon tailwaters reach, and is scheduled for completion under an FY 2000 modification. The study is designed to evaluate all streamflow and sediment-transport data for the Lees Ferry and Grand Canyon streamflow records relative to climate variability, onset of regulation, the Record of Decision, and historical 2-dimensional sand bar changes that have been recorded in aerial photographs between 1952 and the post 1996 Beach/Habitat-Building Flow (BHBF) Test, as well as 3-dimensional changes recorded through cross-section and sand bar surveys. Preliminary mapping results indicates that sand bar areas within some reaches of Marble Canyon were historically largest in 1984, following the 1983 flood flows, even compared with pre-dam eddy conditions. Further, existing time-series coverages for sand bars within existing GIS reaches below river mile 42 show no clear trends for sand bar erosion following closure of Glen Canyon Dam.

Historical pre- and post-dam sediment-transport data suggests that the likelihood for achieving multi-year storage of fine-sediment inputs from the Paria and Little Colorado Rivers

along the main channel is small under Record of Decision flows. In fact, both pre- and post-regulated data suggest that significant aggradation of the main channel bed did not occur on more than a seasonal timeframe except for periods when flows were below about 8,000 cfs. Preliminary synthesis results also show that the major shift in the seasonal pattern of low versus high flows (relative to the fine-sediment input period), resulting from regulation, is a primary reason why multi-year storage potential in the main channel is limited. On the basis of these preliminary research findings, USGS sediment researchers have concluded that optimal fine-sediment conservation may only be achieved in upstream critical reaches by releasing BHBFs during or shortly following major tributary floods (late summer or fall). An alternative might be to keep dam releases at the lower end of the operations range during the fine-sediment input season (July through September) and into winter, until a controlled flood can be released under current hydrologic triggering criteria.

Sand Bar Monitoring (NAU): The annual monitoring of 35 sand bars and associated offshore channel-storage settings was continued after the 1996 BHBF-Test by the Geology Department of Northern Arizona University, with measurements having been made through April 1999. These monitoring data indicate that high-elevation sand bars continued to erode slowly following the 1996 BHBF-Test, but that on average, terrestrial sand bar elevations are still slightly higher than they were before the 1996 BHBF. Low-elevation sand-storage environments (eddies and main channel) associated with the terrestrial sand bars appear to be filled with sand to about the same elevations they were just prior to the 1996 BHBF-Test. The exception to this is based on a single monitoring site in lower Glen Canyon, where the channel-bed elevations offshore from the terrestrial sand bar are higher than in early 1996; likely a result of ungaged tributary inputs of sand to the reach from 1997 through 1998. While it is still not clear what the long-term fate of this sub-sample of monitored sites will be relative to the system-wide sand budget, it is likely that partially eroded sand bars at higher elevations (between 25,000 and 45,000 cfs) would rebuild to higher elevations if another BHBF was released in FY 2000.

Conceptual Model (Ecometric Research, Inc.): Two conceptual modeling workshops and two other related science meetings were convened during 1998 to develop a conceptual physical sub-model. These meetings were attended by most of the cooperating physical scientists, as well

as Timothy Randle of the Bureau of Reclamation and William Jackson of the National Park Service.

On the basis of discussions at these meetings and integration of existing data to develop the numerical conceptual model, several preliminary conclusions about sediment transport and the fine-sediment budget of the ecosystem were identified: (1) the dominant geomorphic setting throughout the main channel where fine-sediment storage occurs is within separation and reattachment sand bars and the lower elevations of eddies; (2) channel-margin sand bars may store large volumes of fine sediment, but existing monitoring cannot document how much this potential storage may be without additional data; (3) on the basis of current sediment transport theory, sand inputs from the Paria and Little Colorado Rivers should not be expected to aggrade the main channel (non-eddies) until discharges are at about 8,000 cfs or lower; (4) eddies are highly effective sediment traps with respect to main channel transport, but only when sediment concentrations are high in the main channel, grain-sizes are small and potential storage space is available within eddies; and (5) current knowledge about exchange rates between the main channel and eddies for fine sediment are mainly derived from empirical data sets, but can be greatly improved through expanded use of sand bar evolution models using approaches similar to those developed by USGS for short study reaches below the confluence of the Little Colorado River.

Biological Resources –

Terrestrial Biological Resources - Since 1998, work associated with terrestrial biological resources has represented data collection efforts in support of eventual long-term monitoring programs. As with sediment resources, the emphasis for biological projects was in moving toward long-term monitoring while transitioning from EIS-related efforts associated with these resources. This transition has included attempts to maintain continuity among data sets that were collected prior to 1996. Little emphasis has been put on research associated with terrestrial biological resources. Current contracts are separated into vegetation (Kearsley, NAU), avifauna (Spence, GCRA), and Kanab ambersnail (Meretsky, SWCA). The following is information provided from these monitoring projects.

Monitoring Vegetation Change along the Colorado River Mainstem - Dr. Michael Kearsley of Northern Arizona University has been involved in measuring vegetation change along the Colorado River corridor since 1993. Data collection efforts have changed from a focus on detailed compositional change that takes place on microhabitat scale (Stevens and Ayers, 1996) to characterizing change at the community or plant associated level. His work over the last two years has been to evaluate and incorporate structural components of vegetation, in addition to identifying changes in the species composition of plant communities. These structural components provide an index of vertical complexity, a variable that affects bird distribution and abundance. Measurements have also been done along shorelines to determine the relative availability of vegetated shoreline, a shoreline habitat utilized by young fish (Converse, et al., 1998). Preliminary results of this research have identified factors affecting availability of shoreline habitat to include discharge, magnitude of fluctuations, and time of year. Other results of this monitoring effort indicate that some community constituents have changed very little (e.g., tamarisk) in their representation and extent, while others are increasing in abundance (arrowweed). These trends suggest that growth rates of arroweed may have implications associated with campable area over the long-term.

Monitoring Avifauna Abundance and Distribution along the Colorado River Mainstem – Dr. John Spence of the Glen Canyon National Recreation Area has been in charge of overseeing a project to monitor bird distribution and abundance along the Colorado River corridor. Included in this project is the monitoring of the endangered southwestern willow flycatcher. The project has determined that abundance and diversity changes in the avifaunal community along the Colorado River corridor is associated with vegetation densities and distance from the dam. Structurally complex vegetation patches like those found from river mile 42 to Cardenas and in the western Grand Canyon support more birds and more species of birds. Glen Canyon is also an area of waterfowl diversity, likely associated with the relatively rich benthic community and lower velocity waters found in this reach. The next year will be spent synthesizing the bird data and evaluating it to provide recommendations for long-term monitoring that can be integrated with habitat data.

Monitoring of Kanab ambersnail Populations and Habitat at Vaseys Paradise – Dr. Vicky Meretsky through SWCA Inc., has been the lead biologist involved with developing population estimates for the Kanab ambersnail (KAS) located at Vaseys Paradise in Grand Canyon. Both available habitat and snail numbers are determined for each trip throughout the year. Trips are conducted on a quarterly basis that coincide with the life history of the snail. Monitoring of the habitat indicate that primary habitat composed of Nasturtium is highly variable in terms of area covered. This plant species is an annual and its area cover is influenced by local climate effects. A warm winter may result in greater growth earlier in the season, while a summer storm event may result in scour of local patches. The variability in habitat is less likely to be observed with Mimulus (monkey flower) the other major plant species associated with KAS. This plant is a perennial species and the variability in area cover should be less than that of Nasturtium. Population estimates for KAS between years has not been shown to be significantly different. However, the confidence intervals around these estimates are great, due to overwintering mortality that can result in high inter-annual variability. The life-history of KAS is characterized by starting with a small number of over-wintering adults. Population size increases throughout the season from recruitment. An associated KAS genetics project (Keim, Northern Arizona University) has provided preliminary indications that the KAS at Vaseys Paradise is genetically distinct from Utah populations also identified as KAS. What this distinction means in taxonomic terms is yet undetermined.

Aquatic Biological Resources - Since 1998, work associated with aquatic biological resources have represented data collection efforts in support of eventual long-term monitoring programs. As with terrestrial biological resources, the emphasis for biological projects is moving toward long-term monitoring while transitioning from EIS-related efforts associated with these resources. This transition has included attempts to maintain continuity among data sets that were collected prior to 1996. There has been a bit more emphasis put on research associated with aquatic resources when compared to terrestrial resource efforts to develop information that will be used in developing the long-term monitoring program. Current contracts are separated into aquatic foodbase (Blinn, NAU), Lees Ferry Trout (Persons, AGFD), and Native Fish

Monitoring (Gorman, US FWS). The following is information provided from these monitoring projects.

Monitoring the Aquatic Foodbase in the Mainstem Colorado River and its Tributaries – Dr. Dean Blinn of Northern Arizona University has been studying aquatic biology of the Colorado River since the 1980s. Efforts since 1998 have focused on monitoring the productivity in the mainstem as influenced by dam operations and understanding the relationship and influence of tributary productivity on the mainstem. Results of these data collection efforts indicate that reducing fluctuations benefits productivity. Productivity is increased because areas available to colonize are stabilized. What is not known is if combinations of stability and short-term disturbance optimize productivity. Productivity increased following the 1996 BHBF, the subsequent flows in the summer of 1996 and in spring/summer 1997 that were high and relatively steady compared to operations in previous years and may have been a contributing factor in the measured productivity. Tributary collections show that these streams are a source for benthic colonizers in the mainstem, but current mainstem conditions (constant cold temperatures) preclude their expansion into the mainstem. Some organisms found in tributaries need a range of temperatures as a growth cue. These cues are not available in the mainstem. Both of these pieces of information are important for managers trying to optimize mainstem productivity. Productivity might be limited by temperature (degree days) and other physical parameters, or by habitat instability (amount of fluctuations), or a combination of the two.

Monitoring the Lees Ferry Trout Fishery – Mr. Bill Persons of the Arizona Game and Fish Department has been overseeing the contract responsible for determining the effects of dam operations on rainbow trout in the Glen Canyon reach. This contract has included the collation of stocking and catch data since the 1960s and an examination of the effects of minimum flows on trout populations. Their analysis concludes that fluctuations conducted during the 1990 research flows caused a decline in the trout population in the Lees Ferry reach. Higher minimum and more stable releases appear to support greater standing stocks of trout than do lower minimum releases and releases with greater variability. These data support the findings

associated with the aquatic foodbase. The full effect of stable releases is not fully realized for up to three years: densities of fish >304 mm declined until 1993. Small fish are more affected by physical factors, suggesting that recruitment is affected by operations. Larger-sized fish are more affected by biological factors (e.g., food availability) which may account for the lag in response to steadier releases by fish > 304 mm. Stock assessments for the Lees Ferry fishery suggest that the larger fish are food-limited. The trout fishery is considered self-sustaining and stocking currently is being suspended in this fishery.

Monitoring of Native and Other Fish in the Mainstem Colorado River and its Tributaries– Dr. Owen Gorman, formerly of the U.S. Fish and Wildlife Service, has been the principal investigator responsible for native fish monitoring in the mainstem since 1998. Work in this project has included mainstem data collection and tributary data collection. The emphasis has been on evaluating recruitment in the tributaries, primarily the Little Colorado River, and characterizing relative abundance of species in the mainstem. The intensity of sampling in the mainstem may not have equaled historic levels, but gear-types are comparable. Data from these monitoring trips indicate that Rainbow Trout is the most common fish, followed by Speckled Dace and Humpback chub in the mainstem. The addition of mini-hoopnet to the sampling regime has resulted in the capture of an increased number of smaller Humpback chub in the mainstem. This result suggests that either gear types are biased against this size fish, that recruitment and survivorship has increased in this size class, or that new habitats are being sampled that were previously not sampled. The latter is not a likely explanation for this data. Included in this contract was research associated with juvenile growth and temperature. Preliminary results indicate that young fish provided unlimited food that are in 12°C water do not grow over a 6-month time period and lose body mass over time. Fish in 18°C and 24°C tanks showed changes in growth rates after the first month–with those fish in the warmest water growing the greatest. These data have direct application for Temperature Control Device (TCD) operations. A question that still needs to be addressed is if the small but now older fish are moved from the 12°C tanks to warmer tanks will they respond in a similar fashion to temperature increases.

Native Fish Syntheses - Additional synthesis and modeling work on native fish has been conducted by SWCA (data integration report), Duncan Patten (compilation of GCES Phase II aquatic biology studies) and Walters, et al. (modeling abundance trends in native fish). Population estimates for Humpback chub in the LCR have been published by Douglas for 1991-1993 and additional estimates for 1993-1995 are in press. In addition, modeling work by Walters, et al. (in preparation), suggests that populations of Humpback chub in the LCR are stable or possibly declining slightly over the period 1991-1996. The work of SWCA highlights the importance of life history parameters on the survival of Humpback chub and points to the potential of predator-prey interactions in addition to temperature as a key factor affecting Humpback chub abundance and distribution in the mainstem. The reviews of GCES Phase II Humpback chub monitoring and research activities by Brunkow (in Patten) will be useful in designing the long-term monitoring program for native fish.

Socio-Cultural –

Cultural Resources – The current information concerning cultural resources is based on a number of previous and ongoing investigations within the Colorado river corridor in the Glen and Grand Canyons conducted by the NPS, Tribal groups, and GCMRC investigators. Cultural resources along the Colorado River corridor include archaeological sites and traditional cultural resources such as springs, landforms, sediment and mineral deposits, and traditional plant locations and animals. The goal of the cultural resource efforts is *in-situ* preservation with minimal impact to the integrity of the resources, and when preservation is not possible, treatment efforts as appropriate. Monitoring activities include site visits, photography, and remedial activities and tribal assessments of traditional cultural resources and the general health of the ecosystem through traditional perspectives.

Cultural resources are monitored regularly and during high flow events. Many of the archaeological resources along the river corridor are contained in the sediment deposits which form the alluvial terraces. Since the completion of Glen Canyon Dam, the sediment resource has declined, and the alluvial terraces have eroded. A system-wide method for regenerating the river terraces and redistributing sediment is generally considered an essential component to maintaining integrity for cultural resources.

Previous Investigations. The 1996 BHBF presented an opportunity to study the effects of high flow discharge from Glen Canyon Dam on alluvial terraces and margin deposits along the river corridor. The flow was expected to provide system-wide mitigation to most cultural sites in the Colorado River corridor through the accumulation of additional sediment and the overall findings of the cultural resources studies strongly suggest that the 45,000 cfs BHBF flow had either no effect, no adverse effect, or a beneficial effect on cultural resources. These findings support the original contention that habitat building flows can offer a system-wide mitigation for cultural resources. Some locations, especially in the Glen Canyon reach, did experience loss of sediments or re-deposition of sediments in a way that, in the long run, could be detrimental to cultural resources.

Ongoing Investigations. Current resource monitoring of archaeological and traditional resources suggests that archaeological resources continue to be impacted by physical impacts such as surface erosion and gullying in both the Grand and Glen Canyon areas. While some surface erosion is due to natural processes that are unrelated to dam operations, sediment loss from erosional processes believed to be related to dam operations and mainstem water levels, and head cutting arroyos appear to impact archaeological sites at specific locations. Visitor impacts such as trailing and collection of artifacts have also been noted at archaeological sites and locations of traditional importance (Leap, et al., 1999). Generally, plant resources seem to be in good condition with some physical and visitor impacts noted at some locations.

Ongoing GCMRC projects will provide additional information that complements previously collected data. These projects include a synthesis of data collected by the NPS and Tribal groups, mainstem flow and deposition modeling, and testing of a geomorphic erosional hypothesis. The data synthesis will help identify data gaps in previously collected data. A stage flow and deposition modeling project will provide information on estimated sediment deposition at selected archaeological resource locations that may result from flow regimes associated with dam operations. These data can then be used to analyze available information on pre-dam processes that affected cultural site preservation. An ongoing geomorphic project is attempting to identify erosional processes that are related to dam operations versus naturally-occurring processes. Results of these studies will be helpful in distinguishing resource impacts that are related to dam operations. Draft reports for the data synthesis and geomorphic projects have been

submitted and are being reviewed. An interim report on the flow and deposition modeling is due later in FY 2000. Ongoing tribal projects include an ethnobotanical project to evaluate traditional plant resources and a public outreach project to disseminate information on traditional tribal resources. Project reports with recommendations are due in FY 2000.

Recreational Resources – Beaches and sand bars serve as campsites for rafting groups and are highly valued based on size, boat mooring quality, wind protection, access to side canyon hikes, scenery, and shade. Historically, these beaches were replenished annually by sand and silt transported by the river during spring runoff. Since this sediment now settles out in Lake Powell, the beaches downstream are eroding due to the river's clear, sediment-free flows (Kearsley, et. al., 1994). Most pre-dam beaches are now considerably smaller, and some have disappeared completely. Camping beaches are also being eroded through gullying induced by monsoon rainstorm runoff, a phenomenon believed to be related to the lowered mainstem base levels as degraded beaches are not replenished by annual flooding.

Previous Investigations. In 1994, change in campable area was analyzed from an inventory of campsites using past aerial photographs (Kearsley, et al., 1994). The effects of the 1996 controlled flood on campsites were evaluated and it was found that the increase in the number and size of campsites was of short of short duration. These data suggest that floods temporarily increase campsite number and size but then campsites will continue to erode slowly. The flood effects to campsites seem temporary but they appear to be the only feasible means of depositing sediment above normal fluctuations (Kearsley, et al., 1999.)

Ongoing Investigations. Ongoing GCMRC studies address campsite assessment and monitoring through quantitative beach and sand bar measurements to detect area and volume change. The results of this work will be available later in FY 2000. An additional recreational study is assessing recreational preferences relative to experiences. This study includes recreational preferences for camping beaches and activities such as white water rafting, day-use rafting in Glen Canyon, and fishing and recreation experiences. Data on beach use frequency is currently being collected by an NPS study and will be available in FY 2001 for use in future studies investigating human impacts to beach sites. Recreational fishing data will be assessed in FY 2000 as part of a protocol assessment that will be conducted in tandem with other trout study

assessments. These data will be available in later in FY 2000.

Information Technologies Program (ITP) –

Data Base Management System (DBMS) – Development of the DBMS has been on hold since the resignation of GCMRC's DBMS Coordinator in August 1998. The Oracle DBMS software has been selected as the data base engine and Windows NT has been selected as the platform. The Oracle DBMS software has been obtained and installed and the installation procedure documented. We have recently filled the DBMS Coordinator position and anticipate moving forward with DBMS development in the very near future.

Geographic Information System (GIS) – Development of the GIS was on hold since the resignation of GCMRC's GIS coordinator in June 1998. A new GIS Coordinator was hired in April 1999. Since then much effort has been dedicated towards remote sensing evaluation and cataloging, and making available legacy-GIS data obtained by GCMRC's predecessor, the GCES program. Much of this data is now available to GCMRC staff and investigators, AMWG/TWG members, and the public through our FTP server at ftp.gcmrc.gov. The FTP server contains spatial coverages of non-sensitive, project-specific data; topographic, geologic, and hydrologic base data at established GIS sites; and remotely-sensed imagery including LIDAR and digital orthophotos. Additional effort has been dedicated toward assembling basin-wide GIS data sets, developing GIS data and metadata standards, preparing for a possible BHBF during the summer of 1999, providing GIS support and training to GCMRC scientists and investigators, and coordinating remote sensing activities.

Library – The GCES made great strides in the establishment of the library in 1993 when a research librarian was hired to organize and maintain it. However, the librarian resigned in May 1997 during the transition from GCES to GCMRC and the position was not immediately backfilled. There have been valid concerns about the condition of the library since that time. New holdings have been stacked on shelves, desks, or placed in boxes for safekeeping. There was no formal monitoring of the library or checkout process to track the whereabouts of library materials. Fortunately, that situation has since been corrected and significant progress has been made in making the library a functional entity within the GCMRC.

A library committee was assembled in October 1998 to decide what actions should be

taken to update and maintain the library. Over several months, the committee produced a strategic plan with recommendations for the restoration of the library. The library contents and strategic plan were reviewed by two outside consultants who each produced written comments and recommendations. Since that time, a student has been hired from Northern Arizona University to oversee the day-to-day operations of the library and reorganize its contents. Library automation software has also been obtained and the library contents are being indexed using this software on a time-available basis.

Surveying - Surveying has been an integral part of science monitoring and research in the Grand Canyon since 1993, starting with the former GCES. In addition to providing general survey support to GCMRC scientists and investigators for spatially-referencing data collected in the field, the survey function provides survey and mapping infrastructure in the form of terrestrial base maps, hydrographic base maps, and control.

Terrestrial base maps - Terrestrial mapping in the Grand Canyon on the Colorado River corridor is required for spatial monitoring of physical, biological, and cultural resources. Terrestrial mapping usually produces a digital terrain model (DTM) in combination with the XYZ position of features and artifacts. Periodic mapping of the same areas can be used for change detection of resources. This data is usually displayed in the form of a contour map.

The two types of terrestrial mapping currently done are field surveys and remotely-sensed data (photogrammetry, LIDAR). Field surveys can yield a very high precision DTM with a contour resolution of 10 centimeters (cm). The accuracy is dependent on the control. Photogrammetry data, as in our GIS sites, are sub-meter precision and are displayed at one half-meter contour. There are a few sites with high-resolution photogrammetry at 20 cm resolution.

It is an objective of GCMRC to establish a sub-meter accuracy terrestrial topographic base map of the entire river corridor to support long-term monitoring. This is only feasible using remotely-sensed data such as photogrammetry or LIDAR.

We currently have sub-meter accuracy terrestrial topographic coverage of approximately 80 miles of the ecosystem in 17 areas of concentrated scientific effort that we refer to as GIS sites (Figure 1.2). We also have similar topography from GCD to Badger Rapid near river mile (RM) 8 and in the Phantom Ranch area derived from our LIDAR evaluation. In 1999, the

GCMRC participated in a cooperative project with the USGS and the National Geodetic Survey to collect geo-referenced stereo photography of the entire Colorado River ecosystem with the objective of evaluating a new procedure for producing sub-meter accuracy terrestrial topographic base maps without the need for ground control. A 25-mile test section of the ecosystem will be mapped as part of the evaluation. The processing costs for the remainder of the ecosystem have yet to be allocated. In addition to sub-meter terrestrial base maps described above, we have high-

Figure 1.2Map showing the Location of 17 GIS Sites for which there are Sub-meter Accuracy Topographic Base Maps Available
(Please open Figure 1.2 file separately - the graphic is large and slows document processing)

Figure 1.2 The location of the 17 GIS sites for which there are sub-meter accuracy topographic base maps available.

resolution field surveys of 35 sand bar sites that have been repeated at varying intervals since 1991. We also have numerous field surveys of vegetation, cultural, and KAS surveys. Additional sub-meter accuracy terrestrial topographic coverage needs to be obtained for the remainder of the ecosystem.

Hydrographic base maps - The Hydrographic mapping program was established for the purpose of obtaining a sub-aqueous channel map of the Colorado River within the ecosystem and measure changes in morphology and volume to monitor sediment. Another important emerging hydrographic technology is the monitoring of grain-size movement and distribution.

The hydrographic single beam system prior to 1999 had an XYZ spatial accuracy of about 25 cm 90 percent of the time. The use of a robotic tracker and motion compensation improved the single beam accuracy to about 5 cm. Using the single beam system, a 10 meter square grid generally yields a reliable 0.5 meter contour resolution and 0.25 meter contour resolution using the new system. A pilot study on a multi-beam hydrographic system, which produces 100 percent coverage of the bottom, yielded a 5 cm contour resolution. Furthermore, the productivity of the multi-beam demonstrated the only feasible method of completing a channel map in a reasonable amount of time.

It is an objective of GCMRC to acquire an in-house multi-beam system to complete a channel map of the entire system. The system would also be used to collect event-driven hydrographic data as well as sediment monitoring. We would also like to incorporate side-scan sonar or bottom classification technology to monitor grain-size distribution and bottom geomorphology.

We currently have low resolution (20 meter transects) single beam base data from GDC to Badger Rapid, and GIS Site 7. We currently have high resolution (10 meter square) single beam data in 35 NAU sand bar sites (repeated since 1993), repeated surveys from Paria (RM 1) to Cathedral Wash (RM 3), 4 large pool sites in Site 5 (Wiele, 1998), 5 repeated surveys in GIS Sites 4 and 5 to monitor the 1996 flood, and a pre and post flood survey on the Lake Mead Delta. We also have extremely high resolution (multi-beam) surveys in the pools from RM 60 to RM 68. Additional channel mapping of all the GIS reaches and the remaining river channel needs to be obtained as control is established.

Canyon control – Survey control in the Colorado River ecosystem is required to meet the demands of any spatial measurements for scientific monitoring and research. Survey control also supports the spatial positioning of hydrographic and bathymetric channel mapping as well as ground control for aerial mapping or remote sensing applications.

The control framework is established with static differential GPS. The desired accuracy for this GPS is centimeter accuracy with millimeter precision. The interconnecting conventional traverse surveying allows for continuous line-of-site point availability as well as network adjustment capability. The desired accuracy for primary conventional control is 10 cm with 1 cm precision. The objective is one primary control point every 500 meters.

We currently have approximately 20 first order GPS grade base stations set on the rim of the Grand Canyon in support of Static Differential GPS. This base station network is currently in good order to complete the control in the Canyon. We additionally have continuous traverse control (point-to-point line of sight) from GDC to RM 72. Downstream from RM 72 there is continuous traverse control in all existing GIS sites. In addition there is continuous traverse control from the LCR confluence to Blue Springs, approximately 14 miles upstream which encompasses GIS Site 15.

There are approximately 50 sites throughout the system that exist outside of GIS areas that use locally-established control points. These sites must be tied in as we bring control into these areas. The list includes NAU sand bar monitoring sites, vegetation monitoring sites, and cultural sites. All the USGS transect bolts have been tied in from GDC to RM 72. Downstream USGS bolts in GIS Sites have also been tied in. USGS bolts that require surveying are at Phantom (RM 90), and National Canyon (RM 160). The GCMRC Survey department objective is to complete the continuous control network in the Canyon in the next three years.

Systems Administration – Systems Administration encompasses the entire computing and networking environment at the GCMRC. The GCMRC computing environment has been substantially upgraded during the past two years with improved intra- and inter-net infrastructure and standardized computer hardware and software. The core computing environment is now, for the most part, stable with the majority of malfunctions attributable to typical glitches associated with all computer environments of similar complexity. One part-time student employee, in conjunction with the IT program manager, currently acts as our systems administrator.

Remote Sensing – There are currently two aspects to GCMRC remote sensing: (1) remotely sensed data collection, and (2) the remote sensing initiative entitled "*Evaluating ground-based and airborne remote sensing technologies*." Remotely-sensed data collection currently consists of annual aerial photography collected during the Labor Day weekend. Black-and-white stereo aerial photography is collected over the entire Colorado River ecosystem and natural color is additionally collected in areas critical to vegetation studies. The GCMRC intends to continue the annual acquisition of aerial photography until other remotely-sensed data sets are identified and implemented into the monitoring program.

The GCMRC remote sensing initiative is currently on hold since the resignation of the GCMRC staff member coordinating the activity in February 1999. The remote sensing initiative formally begins in FY 2000. However, planning and informal activity have been taking place since spring of 1998. In May 1998, a remote sensing protocols evaluation panel (PEP) met to review the remotely-sensed monitoring and research methodology currently used by the GCMRC. The panel recommended alternative remotely-sensed technologies that might better meet science program information needs. The panel's report recommended a number of ground-based and airborne remote sensing technologies that had potential in the Canyon, but the panel did not provide any prioritization of these technologies. It is anticipated that most of these technologies will be evaluated as part of the remote sensing initiative. Some technologies have been evaluated on an accelerated schedule due to related projects funded prior to the remote sensing initiative, pressing needs for technological development in specific monitoring areas, or opportunistic circumstances.

Remote sensing technologies recommended by the PEP and their evaluations initiated in FYs 1998-1999 are:

- Investigating cultural terrace erosion using photogrammetry
- Three-dimensional sand bar measurement using vertical photogrammetry
- Three-dimensional sand bar measurement using oblique photogrammetry
- Bathymetric channel mapping using multibeam sonar
- Channel bed classification using QTCview
- Terrestrial mapping using LIDAR
- GPS comparison to total station as a means of setting control (preliminary)

- Multi-resource monitoring using HYDICE hyperspectral imaging (data collection only)
- Vegetation monitoring using color infrared (data collection only)
- Biomass measurement using LIDAR
- Turbidity using passive optical sensors
- Radiant temperature measurement
- Radiotagging of boulders

Interim products from these pilot tests include:

- Three-dimensional model and DEM of the Glen Canyon reach from Lees Ferry to Badger Rapids produced from LIDAR
- Geo-referenced, ortho-rectified color infrared photography of the Glen Canyon reach which can be used for rectifying additional annual photography and evaluate color infrared as a means of vegetation monitoring
- Cultural terrace maps which can be used for identifying areas of erosion and calculating volumetric changes
- Three-dimensional sand bar maps from which to compute volume changes
- Geo-referenced channel maps of portions of the Lees Ferry reach which can be used for volumetric sediment transport measurements
- Single-beam channel bed classification for portions of the Lees Ferry reach which can be used to classify channel bed material
- Surface-water temperature maps of the Colorado River

These products will be useful to the program whether or not the evaluation yields information suggesting we should implement a given technology in an operational mode as part of GCMRC's long-term monitoring and research. GCMRC is currently evaluating how best to proceed with coordinating the remote sensing initiative. Staffing arrangements under consideration are: (1) utilizing a term appointment to last the three year duration of the initiative within GCMRC, (2) utilizing a cooperative agreement with experienced personnel from another agency within the Federal government, and (3) contracting the evaluation to an external third party.

PROGRAM INTEGRATION

All GCMRC monitoring and research programs utilize ecosystem science approaches that require integrated studies (Figure 1.3) that conform to the appropriate spatial and temporal scales of the issues at hand. As the report of the Ecological Society of America Committee on the Scientific Basis of Ecosystem Management (ESA, 1995) indicates, the incorporation of good science into management decisions at a landscape level is an essential component of ecosystem management. An ecosystem approach will serve to advance both scientific understanding and management capabilities, while supporting protection, management, and use of natural resources.

MANAGEMENT OBJECTIVES AND INFORMATION NEEDS

The monitoring and research activities proposed in the FY 2001 Work Plan are intended to address the management objectives and prioritized information needs recommended by the AMWG to the Secretary and approved by the Secretary for use in developing priorities for monitoring and research activities for the Colorado River ecosystem. MOs and INs 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 MOs and INs have been developed by the Technical Work Group (TWG) and adopted by the AMWG (see Appendix 2.) The specific MOs and INs addressed by the monitoring and research activities proposed in this plan are listed in Chapter 2 in table format, and referenced in the project descriptions.

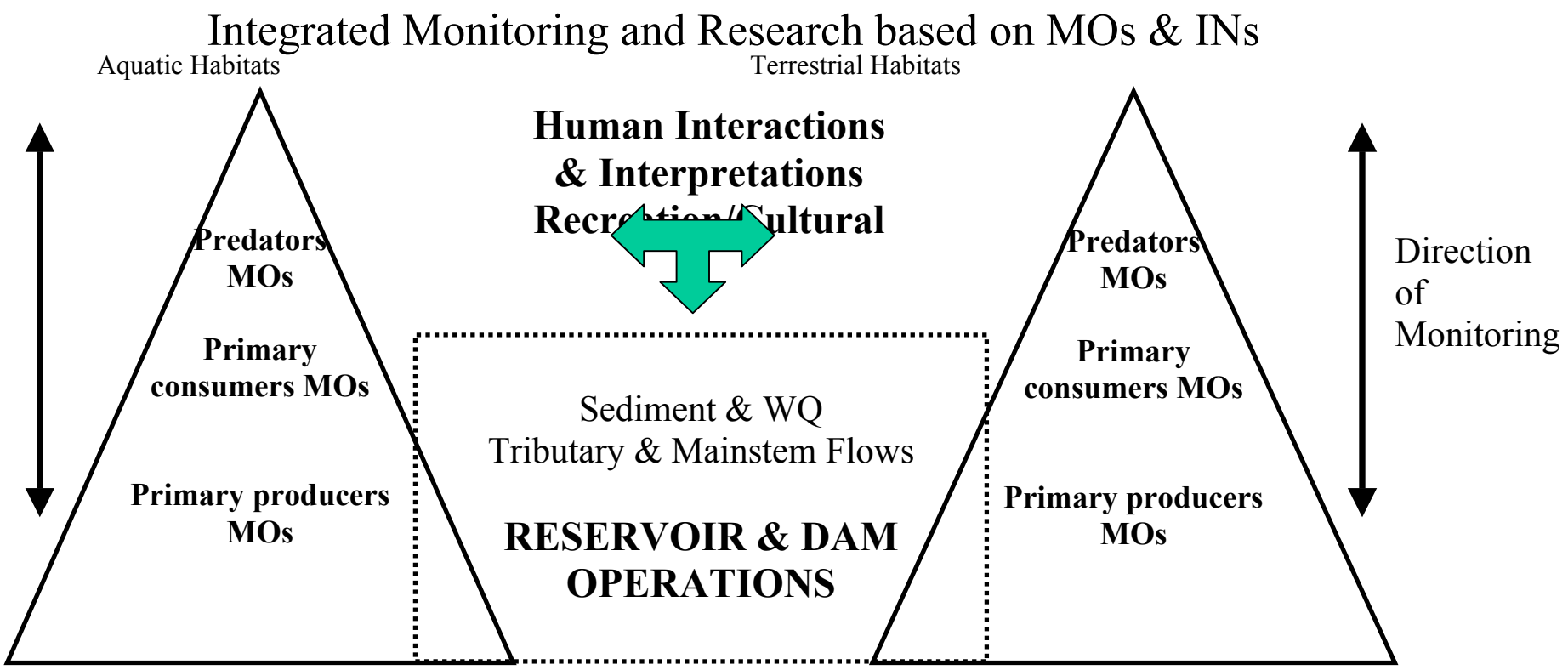

Figure 1.3 Integrated Long-term Monitoring and Research Program

PROTOCOL EVALUATION PROGRAM

The Protocol Evaluation Program (PEP), is described in a prospectus entitled, "Prospectus for Evaluating GCMRC Monitoring Protocols for the Colorado River Ecosystem" (Appendix 3). The information gained through the PEP process is intended to support decisions by the GCMRC Chief and his staff as to the specific monitoring protocols that will be used within the ecosystem. Details on the specific monitoring techniques will be discussed with the TWG and the Science Advisory Board (SAB), and conveyed through RFPs to prospective cooperators that are selected through a competitive process. Although technologies, science and management needs may cause evolution in monitoring protocols and strategies through time, the GCMRC is committed to ensuring that all monitoring data sets are comparable to the greatest extent possible with previously collected information.

The PEP process for evaluating current and new alternative protocols in all program resources area is scheduled for completion by the end of FY 2002. A PEP review workshop on remote-sensing technologies was held in May 1998. PEP review workshops for physical resource monitoring were held in August 1998, and 1999. Reports on the results of those meetings have been submitted to the GCMRC and distributed to the TWG and AMWG. PEP activities in FYs 2000 and 2001 will focus on protocols that support long-term monitoring of biological, cultural and social resources. All PEP workshops and evaluations are conducted in cooperation with external experts identified through a nationwide scoping and competitive selection process, as well as GCMRC science cooperators, contractors, and Technical Work Group members.

CONTINGENCY PLANNING

The TWG and AMWG have adopted hydrologic criteria and resource criteria for triggering managed high flood flows from Glen Canyon Dam (BHBFs). When triggered, these criteria provide little lead time for monitoring and research planning. In addition, hydrologic conditions can lead to unplanned release events which will also require GCMRC to implement monitoring and research activities with little to no lead time. The potential for these events to occur results in the need for contingency planning. Annually, GCMRC will develop contingency plans for implementation of:

(1) supplemental monitoring before and (or) after unplanned events, as appropriate;
(2) research assessments of "flood flows" (as per the GCDEIS) or other short-duration high flow unplanned events; and
(3) a supplemental monitoring and research program for planned events between January-July of a given year.

Funding to support monitoring and research activities beyond those which constitute annual monitoring activities will be sought from the Bureau of Reclamation and the Western Area Power Administration subject to the recommendation of the AMWG/TWG. An example of an outline for a BHBF contingency plan and the associated budget (developed in FY 1999 but never implemented) can be found in Appendix 4.

SCIENCE SYMPOSIUM

The GCMRC has initiated a program of regular scientific symposia to discuss the current state of the knowledge of scientific regarding the Colorado River ecosystem, as well as to learn about similar research in other systems. The GCMRC convenes a biennial Colorado River ecosystem science symposium, and between these years GCMRC program managers and participating scientists make presentations at the biennial Colorado Plateau symposium hosted by the Colorado Plateau Field Station of the Biological Resources Division of the USGS. GCMRC hosted scientific symposia in 1997 and 1999, and will do so again in FY 2001. Typically, these meetings are held in late Winter to early Spring.

FUTURE CHALLENGES

GCMRC and the adaptive management program, in general, face a number of challenges with respect to designing monitoring and research activities to gather information on specific experimental management actions. These include potentially both the construction and operation of a temperature control device (TCD) on Glen Canyon Dam and the implementation of seasonally adjusted steady flows (SASF).

With respect to the construction and operation of a TCD, the FY 2001 Work Plan is based on the assumption that the TCD, if built, will not be operational until FY 2002. The TCD workshop held at Saguaro Lake Ranch from November 8-10, 1999, identified a number of issues that need to be addressed in a monitoring and research plan for the TCD as well as for baseline monitoring. Finally, it is based on the assumption that any activities required to supplement the planned monitoring and research activities will be supported out of Reclamation's Section 8 funds. With respect to implementation of SASF, the FY 2001 Work Plan is based on the following assumptions. First, that the actual flows to be implemented under the SASF experiment will result from the plan being drafted for GCMRC by SWCA, Inc. Second, we assume that there are two possible scenarios for implementing SASFs. The first assumes that a decision is made in January 2001, for implementation of SASFs in FY 2001. Under this scenario, GCMRC would write and release RFPs in April 2000 for any additional monitoring and research activities that are required. Again, we would expect to support this additional work with Section 8 funds. The second scenario is based on the assumption that the decision to implement SASFs is not made until January 2001, and any supplemental activities are implemented through GCMRC in-house activities and modifications to existing contracts. Again, we would expect to support this additional work from Section 8 funds. Until the SWCA, Inc., plan has undergone external peer review and is accepted by GCMRC, no planning is being done regarding additional monitoring and research activities that may be needed in support of SASFs.

SCHEDULE AND BUDGET[8]

The Annual Work Plan and budget described in this document were reviewed by the TWG in Fall 1999, and the AMWG recommended at their January 20-21, 2000, meeting that it be approved by the Secretary for implementation. The GCMRC FY 2001 Work Plan will be implemented for approximately $7 million. Of this amount, $6.434 million is provided through the GCDAMP from power revenues, $300,000 is provided from Reclamation through Operation and Maintenance funds, and $310,000 is provided from Reclamation through Section 8 funds. In addition to these monies, the GCDAMP expends an additional $1.416 million in support of the adaptive management process and the Programmatic Agreement. For additional information about AMP activities and budget, and the Programmatic Agreement, please contact Mr. Randall Peterson at the Bureau of Reclamation, Salt Lake City, Utah.

[8] The budget for the FY 2001 Work Plan was recommended to the Secretary for adoption by the AMWG at its July 21-22, 1999 meeting.